ENVIRONMENT ONTARIO RESEARCH REPORT

SUPPLEMENTARY ANALYSIS OF NOVEL DATA COLLECTED DURING A SURVEY OF RIVERS AND BEACHES IN 1983

January 1988

prepared for

Ontario Ministry of the Environment

RAC Pr ject No. 89 PL

by

University of Toronto
Department of Microbiology

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RAC Project No. 89 PL

by

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Acknowledgement

This work was supported by research project number 89 PL from the Ontario Ministry of the Environment. The manuscript was prepared by Nancy Elizabeth Lightfoot. Professor D.F. Andrews and Mrs. V. Stagg of the Clinical Research Support Unit at the University of Toronto provided statistical and computer science advice.

Disclaimer

This report has been prepared for the Research Advisory Committee, Ministry of the Environment in fullfillment of the terms of the grant. The views expressed herein are those of the authors and they do not necessarily reflect the views and policies of the Ontario Ministry of the Environment.

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ABSTRACT

During the summer of 1983, a prospective study of swimming-related illness was conducted at six freshwater beaches in Southern Ontario. Surface water samples collected were analyzed for specific bacteria and viruses. Some of the beaches were closed for swimming during the summer due to high fecal coliform counts. The overall fecal coliform geometric mean data (432), and fecal coliform geometric mean data for both the open (423), and closed (453) beaches, surpassed the Ontario guideline of 100 fecal coliforms per 100 mL of water. Data were acquired for 8420 people, including: 6653 swimmers, 574 waders, and 1193 people who did not go into the water. Crude morbidity data revealed a general trend of greater morbidity in swimmers, versus waders, versus persons who did not go into the water. For overall illness, the crude symptom rates were: 76.8 per 1000 swimmers, 41.8 per 1000 waders, and 19.3 per 1000 persons who did not enter the water. For all categories of water exposure, respiratory and gastrointestinal symptoms figured predominantly. Logistic regression modelling (n=8420) for overall illness (i.e. all types of illness) generally revealed that swimmers were at significantly increased risk of becoming ill in contrast to persons who did not go into the water (despite inclusion of factors deemed important to the model), and also that

waders were at lower risk than swimmers, when they were compared to persons who did not go into the water, but the magnitude of their risk was debatable. Such modelling of swimmers (n=6653), for various types of illness (i.e. overall and specific types of illness), generally revealed that the illness increased as the bacterial counts increased, but the increase was not significant at the 5% level. There was no evidence to suggest that bacterial count contributed to the prediction of illness in swimmers in most models. The following were found to be important to the models: age, contact person, and interviewer (in all models), and occassionally: sex, beach, and swimming before or after the interview day. Whether or not the bacterial count results are real must be treated with caution, and future investigators must consider the possible effects of various factors. Logistic regression testing of the American and Ontario fecal coliform guidelines, for recreational waters, revealed that the Ontario guideline was more effective in predicting illness in swimmers. At present, it is recommended that this Ontario guideline remain unchanged, and that the following be employed as recreational fresh water quality indicators: fecal coliforms, *E. coli*, *P. aeruginosa* (on mPA), and total staphylococci.

RÉSUMÉ

Dans le courant de l'été 1983, on a effectué une étude prospective des affections liées à la baignade, à six plages lacustres du sud de l'Ontario. On a prélevé des échantillons d'eau de surface, qu'on a analysés en vue d'y détecter certains virus et bactéries spécifiques. La baignade était interdite à certaines de ces plages pendant l'été en question, à cause de taux élevés de coliformes. La moyenne géométrique globale des coliformes (432), et la moyenne géométrique des coliformes pour les plages à baignade autorisée (423) et à baignade interdite (453), dépassait les directives ontariennes de 100 coliformes dans 100 mL d'eau. Les données ont été recueillies auprès de 8 420 personnes, ainsi réparties : 6 653 baigneurs, 574 «barboteurs» et 1 193 personnes qui n'étaient pas allées dans l'eau. Les données brutes de morbidité ont révélé une tendance générale à une morbidité plus élevée chez les baigneurs, par comparaison avec les barboteurs et les personnes qui n'étaient pas allées dans l'eau. Toutes affections confondues, les taux bruts de symptômes étaient de 76,8 pour 1 000 chez les baigneurs, 41,8 pour 1 000 chez les barboteurs et 19,3 pour 1 000 chez les personnes qui n'étaient pas allées dans l'eau. Pour toutes les catégories ayant été en contact avec l'eau, les symptômes d'affections respiratoires et gastro-intestinales prédominaient. Une modélisation logistique par régression (n=8 420) pour toutes les affections confondues, a révélé de façon générale que les baigneurs risquaient beaucoup plus de souffrir d'affections que les personnes qui n'étaient pas allées dans l'eau (malgré l'inclusion de facteurs considérés comme importants pour le modèle), et également que les barboteurs étaient moins exposés que les baigneurs, par comparaison avec les personnes qui n'étaient pas allées dans

l'eau, l'ampleur du risque restant matière à discussion. Une modélisation semblable pour les baigneurs (n=6 653), pour les diverses sortes d'affections (c'est-à-dire toutes affections confondues et affections particulières), a révélé de façon générale que la fréquence des affections augmentait parallèlement à l'augmentation du taux de bactéries, mais que l'augmentation n'était pas sensible au niveau de 5 %. Dans la plupart des modèles, aucune preuve n'autorisait à penser que le taux de bactéries pouvait contribuer au pronostic de maladies chez les baigneurs. Voici les facteurs dont on a constaté l'importance pour les modèles : l'âge, la personne contact et l'enquêteur (pour tous les modèles), et, occasionnellement : le sexe, la plage et le fait de s'être baigné avant ou après le jour du questionnaire. L'exactitude des comptages bactériologiques est sujette à caution et lors d'enquêtes ultérieures, il faudra tenir compte des effets possibles de divers facteurs. L'essai logistique par régression des lignes directrices américaines et ontariennes en matière de coliformes, pour les eaux réservées aux loisirs, a révélé que les lignes directrices ontariennes permettaient un pronostic plus efficace des affections chez les baigneurs. Dans l'état actuel des choses, on recommande de n'apporter aucune modification aux lignes directrices ontariennes et d'employer les germes suivants comme indicateurs de la qualité des eaux douces réservées aux loisirs : coliformes d'origine fécale, E. Coli, P. aeruginosa (sur mPA), et staphylocoques.

CONCLUSIONS

As may be seen from the Abstract, in this particular study the microbial counts did not significantly aid in the prediction of illness in swimmers. Nonetheless, several important issues have been raised as a result of this work:

1. microbial sampling methods may require modification (for example, two water samples collected daily may not describe individual exposure experience accurately);
2. other microbial indices may merit attention;
3. more importantly, individual susceptibilities related to water exposure would be difficult to control;
4. there may be a flaw in the experimental design in that it may be necessary to personally speak to each individual interviewed and to obtain medical confirmation of the symptom onset date;
5. the relationship between bacterial count and illness may be far more complicated, mathematically, than thought (for example, a threshold effect may exist); and, finally,
6. the scope of the study described herein may have been too broad.

It should be stressed that this is the most thorough and statistically competent study described to date. Although earlier microbiological - epidemiological surveys were valuable, they each had certain flaws. Cabelli _et al_, for example, clustered data, did not include potential confounders, used a much more simplistic model and grouped those exposed to the water, but who did not put their head under, with persons who did not go into the water.

Our 1980 survey of 10 Ontario beaches used mixed methods of follow-up, and ultimately utilized only the telephone follow-up data. In addition, the interviewer effect was not considered and, when fewer than 50 swimmers were present at a beach, the data was not incorporated in the analysis. Unlike the study described herein, the swimmers and waders in the 1980 study were grouped collectively for analysis.

RECOMMENDATIONS

1. This study revealed that the Ontario guideline of 100 fecal coliforms per 100 mL of water was more effective in predicting swimmer illness than the American guideline of 200 fecal coliforms per 100 mL. This would suggest that our guideline should not be adjusted and if an *E. coli* guideline is adopted it should be set at a concentration that will provide the same level of protection to swimmers.
2. In future microbiological - epidemiological studies water samples for analysis should be collected at depths of 0.5, 1.0, and 1.5 meters. This would help determine the health risk to bathers who remain in a shallow water area.
3. The impact of untreated combined and storm sewer outfalls on the rate of bather illness should be investigated in future studies.
4. The survival rates of potential pathogens in the sediment at beach sites should be assessed.

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CHAPTER 1

INTRODUCTION

1.1 Sources of microbial contamination

Swimming in recreational water represents a very popular pastime throughout the inhabited world (Favero, 1985). The number of swimmers at public beaches continues to rise along with increases in population density. At present, both urban and rural inhabitants generally find nearby beaches to be easily accessible. Public distress, often heightened by the media, is apparent when pristine beaches are polluted by microbial matter of animal, human, agricultural, industrial, and vegetative origin, as well as by chemical waste. Microbial contamination, particularly of bacterial origin, represents a central theme of this thesis.

Recreational waters may contain a variety of microbes which can originate from a number of sources (Brown, 1983; Cabelli, 1978; Geldreich, 1972). These microbes may be either nonpathogenic or pathogenic in nature. This chapter focuses on four important themes:

1. The potential sources of microbial contamination found in recreational waters, and the role of meteorological conditions in influencing the amount of microbial contamination.
2. The importance of previous microbial water quality studies.

3. The nature of the infectious diseases associated with exposure to microbes in recreational waters.
4. The existing indicators and guidelines for microbial recreational water quality.

It is within this framework that an epidemiological investigation of swimming-related illness in fresh water recreational areas in Southern Ontario is presented.

1.1.1 Human and animal contamination

Swimmers are susceptible not only to a variety of bacteria associated with humans (Brown, 1983), but also to some bacteria found in animals (Dimitracopoulos et al., 1977). For example, coagulase testing of Staphylococcus aureus strains isolated using rectal swabs from apparently healthy cows detected human, animal, and intermediate biotypes.

Close to shorelines, microbial pollution from birds may be an important source of contamination (Gould and Fletcher, 1978). Gould and Fletcher have observed gulls roosting on inland waters, and feeding at garbage dumps, sewage works, and sewage outfalls. Daily bacterial output monitoring revealed that detectable detrimental effects upon bacterial water quality may occur when a large number of gulls roost upon confined water bodies. This is most noticeable where dispersion and dilution of fecal material is minimal (Gould and Fletcher, 1978). The rapid increase in the gull population over this century has produced a

dramatic increase in this type of contamination (Gould and Fletcher, 1978).

1.1.2 Relative contributions from human and animal bacterial sources

The extent to which humans and animals may contribute to the bacterial content of recreational waters is apparent from the examination of daily fecal coliform production rates. Daily loads for fecal coliforms - the North American bacteriological recreational water quality indicator of choice - were as follows (in numerical order): 110×10^8 for ducks, 50×10^8 for lesser black-backed gulls, 19×10^8 for humans ,18×10^8 for herring gulls, 6.2×10^8 for common gulls, 3×10^8 for black-headed gulls, 2×10^8 for chickens, and 1.3×10^8 for turkeys (Gould and Fletcher, 1978; Geldreich, 1966). In comparison, Jones _et al_. (1984) provided the following estimates for the daily loads of _Escherichia coli_ - bacteria which are associated almost exclusively with human and animal sources (once again in order of decreasing magnitude): 8.9×10^9 for hogs, 5.4×10^9 for cows, 2.4×10^9 for chickens, 2×10^9 for gulls, 1.9×10^9 for humans, and 1.3×10^9 for turkeys. These investigators also revealed that the _E. coli_ concentration per 100 mL ranged from 3.4×10^5 to 2.8×10^7 in some sewage samples; in some sewage effluent samples, the _E. coli_ concentration ranged from 1×10^3 to 1×10^7 per 100 mL. Jones and White (1984) estimated that _E. coli_ has a mean

90 per cent survival time of 62.3 h in freshwater, in contrast to 2.3 h in seawater.

1.1.3 Implications of meteorological conditions to bacterial density and associated methods of control

Standridge *et al.* (1979) found that high fecal coliform counts at a Wisconsin beach during the late summer and early fall of 1978 could be attributed to mallard duck excrement and meteorological events (i.e. rainfall in excess of 1.2 cm/day, or onshore winds in excess of 20 mph for at least 3 h/day). The duck excrement was presumed to be introduced into the water by runoff, wind, erosion, and the actions of swimmers.

Meteorological investigations undertaken by Seyfried (1973) focused upon the importance of sunlight in the reduction of aquatic bacterial densities. Samples taken from Toronto Harbour and Lake Ontario, Canada, on clear sunny days, cloudy days, and days on which high air pollution conditions prevailed, were analyzed for heterotrophic bacteria, fecal coliforms, and fecal streptococcal densities. Interestingly, she found that the counts began to decrease at 1200 h and reached a low point at 1500 h on sunny days. In contrast, this trend was not apparent on cloudy days, or when high air pollution indicies were recorded.

Faust *et al.* (1975) examined the estuarine ecosystem, and found that for fecally derived *E. coli*, the density was

most dependent upon water temperature, and that salinity, time, and dissolved oxygen were of lesser importance. Experimental studies were performed over a temperature range from 5 to 30^{o}C, at 5^{o}C intervals. Water temperature was found to be inversely related to E. coli survival. Lower temperatures prolonged E. coli survival, while higher temperatures effectively reduced the E. coli density. Presumably, this reflects the slower metabolic rates and the presence of larger quantities of dissolved oxygen in cooler water (Faust et al., 1975).

In a study conducted on Buffalo Lake (Texas), during the months of May, June, and July, 1968, Geldreich (1972) evaluated the role of meteorological conditions in fecal contamination of recreational waters. He also investigated the methods of controlling fecal pollution of such waters. Bathing water quality was rated as being excellent during long dry weather periods (the median fecal coliform value from 48 samples at six sample locations was 7 per 100 mL of water). Marked deterioration of water quality was evident as a result of stormwater runoff arising from infrequent heavy thunder showers (when the fecal coliform values surpassed the 200 organisms per 100 mL limit set by the United States Environmental Protection Agency (Geldreich, 1972; National Technical Advisory Committee, 1968; U.S. Environmental Protection Agency, 1976)).

Despite the fact that Geldreich (1972) failed to detect a significant public health hazard to recreationalists on the lake, it was felt that fecal

contamination of bathing water could increase the likelihood of the appearance of enteroviruses, Salmonella sp., Leptospira sp., or other pathogens which might attain an infective dose level and pose serious health risks to swimmers.

Geldreich (1972) outlined the following measures in order to control fecal contamination in recreational waters:

1. Restriction of swimming and water skiing was advocated when rainfall produces a run-off in excess of 5.6 x 10^5 m^3. This restriction could be lifted when the results from the bacterial monitors improve sufficiently.

2. Effective waste management of cattle feedlot operations was proposed. For example, the utilization of diversion channels to transport waste into stabilization ponds for 30 day periods prior to discharge into streams.

3. A reduction in the bacteriological oxidation demand from 85 to 90 per cent to a lower value was recommended. Subsequent chlorination of this effluent before discharge into recreational waters during peak seasons was also suggested.

4. Restriction on the horsepower limit and total number of motorboats on the lake was suggested in order to prevent resuspension of settled fecal waste. This would reduce the amount of mobilization of pathogens which can survive in sediments for several weeks.

5. Maintenance of a buffer zone between wildlife areas and recreational waters in the lake was proposed.

Geldreich (1981) focused attention on the relative significance of urban and rural runoff on the microbial content of recreational waters. Soil, vegetation, decomposing organics, animal wastes, marginally treated and untreated sewage, and waste from industry were all found to contribute to microbial densities in recreational waters. He emphasized that nearshore waters - those within 3 km of the shoreline - are subject to the worst contamination from municipal sewage, industrially treated effluents, and uncontrolled additions of urban and rural stormwater runoff.

1.1.4 Contributions from landfills and sewage plants to bacterial densities of waters

Investigations undertaken by Geldreich (1972) have revealed that leakages from landfill operations, cattle feedlot runoff, irrigation practices, and mine drainage can markedly alter water purity. Besides fecal contamination, Geldreich observed that the following pathogenic organisms have been detected in polluted waters at one time or another: Salmonella sp., Shigella sp., Leptospira sp., enteropathogenic E. coli, Mycobacterium sp., Pasteurella sp., Vibrio sp., enteroviruses, cysts of Entamoeba histolytica, and hookworm larvae. However, Geldreich noted that most organisms other than Salmonella sp. are detected only infrequently. Geldreich believes that human feces and sewage contribute the majority of waterborne pathogens.

Bacterial pathogens of animal origin reflect the prevalent human and animal population pathogens at any particular time (Geldreich, 1972). Bacterial indicator systems are utilized to detect and measure fecal pollution from all warm-blooded animals because of the extreme variability in the occurrence and density of bacterial pathogens in polluted waters and animal feces.

1.1.5 Sources of viral pollution

Previous discussions have dwelt largely upon bacterial pollution. Viral pollution can also lead to dangerous public health situations. The problem of viruses in sewage has been addressed by Subrahmanyan (1977). Since viruses in sewage are likely to be adsorbed by fecal solids and other particulates, he suggested that sewage sludge - the solid form of sewage - will contain considerable quantities of viruses which could, under suitable conditions, be released and become a potential health hazard. He reported that residential area sewage frequently contains human pathogens such as enteric viruses. In addition, experimental addition of enteroviruses to sewage sludge indicated that most viruses survived for many weeks at room temperature. Subrahmanyan concluded that both sewage effluent and sludge must be treated to avoid contamination of this type.

More than 100 viruses are excreted fecally by humans, according to Feachem et al. (1982). Groups of viruses in this category include: the enteroviruses (poliovirus,

coxsackievirus A, coxsackievirus B, echoviruses, and newly identified enteroviruses), the adenoviruses, reoviruses, astroviruses, caliciviruses, hepatitis A viruses, rotaviruses, coronaviruses, the Norwalk agent, and other small viruses. In addition, it was revealed that a few of the enteroviruses might survive for many months in surface waters, although 90 per cent reduction is normally attained within a few days, and 99 per cent reduction tends to occur within a month - water temperature being the most important contributing factor. In approximately ten days, 99 per cent reduction could be expected at 20^{o}C, although prolonged survival might occur in heavily polluted, or surprisingly, very clean waters (Feachem et al., 1982). Enterovirus survival was reportedly more prolonged in freshwater than in seawater.

1.1.6 Remedies for potential health problems

In order to remedy some of the potential health problems associated with sewage microorganisms, disinfection may be accomplished by:

1. Chlorination using chlorine, hypochlorite solution, or chlorin dioxide.
2. Ultraviolet radiation.
3. Ozonation (Young and Toms, 1981).

Young and Toms (1981) emphasized the need to take safety precautions with these various methods, as both ozonation and chlorination pose potentially detrimental

health effects. Chlorination was criticized by Anderson _et al_. (1982) due to:

1. Carcinogenic effects.
2. Mutagenic effects.
3. Toxicity to aquatic species.
4. Explosive properties.

Thus, Anderson _et al_. (1982) suggested these alternative chemical disinfectants to chlorination: chlorine dioxide, bromine chloride, and ozone. Despite, the fact that they are more expensive than chlorination, their aquatic toxic effects are undetermined. Further testing is clearly required.

Ultraviolet light and sonication are being considered as non-chemical disinfectants (Anderson _et al_., 1982).

1.2 Bacterial recreational water quality studies and proposals

Bacterial recreational water quality studies have stimulated research into a variety of areas.

In 1977, Brenniman _et al_. (1981) conducted investigations at two beaches on Lake Erie. The day on which weekend collection was made, the time of collection, and the locations of the collected samples were evaluated in terms of the methodology. Water samples were collected 10 cm below the surface of the water at: knee depth, chest depth, and at the maximum depth within the swimming areas. Five samples at the various depths were collected (three at

chest depth, one from knee depth, and one at the deepest part of the swimming area) at three times (0900 h, 1200 h, and 1500 h) on Saturday and Sunday for three consecutive weekends commencing in mid-July. Bacterial analysis was undertaken for: total coliforms, fecal coliforms, *E. coli*, fecal streptococci, *P. aeruginosa*, and total staphylococcal concentrations. In general, the arithmetic mean concentrations of these organisms tended to vary significantly ($p<0.05$) between the different sample times for each day. However, the arithmetic mean concentrations of these organisms did not vary significantly ($p>0.05$) at various locations within the swimming area. Brenniman *et al.* (1981) postulated that the water quality at the two beaches was probably homogeneous. However, they advocated the collection of multiple water samples in bathing areas in which there is poor dispersion of fecal waste.

Various small freshwater lakes in Southern Ontario were surveyed for bacterial water quality purposes from 1970 to 1977 inclusive (Hendry and Leggatt, 1982). Results from these studies revealed the importance of location and nature of the water body in bacteriological sampling of bathing waters. Water samples were obtained on five consecutive days in the spring, summer, and fall. Because bacterial levels at stream mouths tended to be ten times higher than those in lake bodies, recreational usage of areas surrounding stream mouths was discouraged.

Further investigation of the role of location in relation to bacterial water quality was undertaken by the

Ontario Ministry of the Environment (1983) in Canada. They instigated the Toronto Area Watershed Management Strategy Study in 1981. Efforts were focused upon the examination of the Don and the Humber Rivers as well as Mimico Creek, in Ontario, Canada. Urbanized watershed positions displayed the poorest water qualities. The West and Main Humber River tributaries displayed fairly good water quality in the sections closest to their sources. However, further down the tributaries, progressive deterioration in the water quality was apparent. As a result of extensive bacterial contamination of surface waters, restricted bather activity was recommended at certain locations in the watersheds. Urban stormwater runoff, along with sewer overflows and sewage treatment plant effluents, appeared to be important in the reduction of stream water quality. Particularly noticeable were the increases in nutrient levels, bacterial counts, and heavy metal concentrations.

Due to the introduction of bacterial water quality monitoring by many Canadian provinces and American states, various recommendations and restrictions have arisen. In order to develop some consistency in the methodology of sampling, further studies must address the following important issues:

1. The number of samples collected and the frequency with which they are taken within a given day.
2. The effects of meteorological events.

Undoubtedly, sample design is a crucial issue in the determination of acceptable bacterial guidelines.

1.3 Virological recreational water quality studies and recommendations

In the area of viral recreational water quality studies, isolation and identification have been of primary interest, whereas in the bacterial area, major concern has been shown for factors which influence bacterial densities. This is because bacterial isolation and identification is so much easier and more advanced than viral isolation.

A study undertaken in June through August of 1980 at selected bathing beaches (concurrent with the epidemiological and bacteriological investigations performed by Seyfried et al., 1985a,b) and sewage treatment plants in Southern Ontario, revealed that of 20 surface water and 11 sediment samples obtained from beaches on the Great Lakes, no virus isolations were made (Jenkins and Cherwinsky, 1981). The same investigators found that three of seven surface water samples, collected from recreational areas on two rivers where bathing was permitted, tested positive for viruses. Of 69 samples collected from four sewage treatment plants and their receiving waters, viruses were isolated from 37 (54 per cent) of the samples. Electron microscopic examination of some of the virus isolated detected the presence of enteroviruses and reoviruses.

Sekla et al. (1980) isolated enteric viruses from 61.8 per cent of sewage samples, 20.5 per cent of effluent

samples, 3.0 per cent of river water samples, and 6.7 per cent of drinking water samples collected from a Manitoba waterway system. The authors noted that the presence of enteric virus in water is a potential health hazard when the water is used for drinking, recreational purposes, or irrigation. Continued monitoring of water treatment plants was advocated.

Surface water systems on two rivers and three marine beaches were examined in Barcelona, Spain, in June, 1974 (Lucena et al., 1982). Viruses were recovered from all the samples analyzed from both rivers, as well as from 70 per cent of the marine samples. It was apparent that the survival of viruses in seawater outlasted that of fecal coliform and fecal streptococci bacteria. The density of both fecal coliforms and fecal streptococci decreased from between two to three logarithmic cycles when measured from 2 to 1000 m from the wastewater outfall. In contrast, the viral density showed no commensurate decrease.

Between January, 1970 and December, 1979, an extensive study of viral contamination in surface waters was conducted by Walter et al. (1982) in West Germany. Recreational waters were found to contain viruses in 20 to 30 per cent of the samples. Samples were also acquired from drinking water and sources containted by sewage. The viruses isolated from 30 sampling points in various surface waters (i.e.: recreational waters, drinking water sources, and sewage contaminated water) over the study period included: polioviruses types 1, 2, and 3, echoviruses types

6, 11, and 30, and coxsackieviruses B3 and B5. In addition, echoviruses types 7 and 24, coxsackievirus B1, and adenovirus 5 were observed in a few of the samples. The overall virus isolation rate ranged from 8 to 92 per cent with a mean of 20 per cent. Waters used for recreational or drinking purposes should be subjected to treatment and disinfection, according to Walter et al.

1.4 Waterborne disease

McNeill (1985) outlined several pathogenic microbes and parasites which may be transmitted by waterborne and water contact (i.e. those transmitted by direct contact with contaminated water in contrast to ingestion) routes (Tables 1.1 and 1.2), as well as some of their human minimum infective doses (Table 1.3).

Waterborne disease is reported more frequently for drinking waters than for recreational waters (McCabe, 1977). Presumably, this is because of the larger number of persons routinely exposed, their greater susceptibility associated with more frequent ingestion, and the larger volumes of water consumed. Significantly, McCabe also revealed that there have been no systematic tabulations of waterborne disease outbreaks associated with recreational waters. Although literature reviews by McCabe (1977) have indicated that such occurrences are rare, some of the more recent outbreaks merit further examination.

In the summer of 1972, Hawley et al. (1973) studied an outbreak of coxsackievirus B5 at a boys summer camp in Lake

Table 1.1 Human Pathogenic Micro-organisms Potentially Water-borne[a]

Infection Category/ Pathogen	Major Reservoir	(b)	(c)	(d)	(e)	Clinical syndrome
FECAL-ORAL / BACTERIA						
Vibrio cholerae	human	0	30 d	high	low	cholera (1-5% of infections)
Salmonella typhi	human	0	60 d	high	low	typhoid fever
Other salmonellae	feral, domestic animals; (human)	0	1 y	high	low	gastroenteritis
Shigella spp.	human	0	40 d	medium	low	shigellosis ('bacillary dysentery')
Enterotoxigenic *E. coli*	human	0	1 y	high	low	diarrhoea
Yersinia enterocolitica	feral, domestic animals; (human)	0	6 m	high	low	includes enteritis, ileitis
Campylobacter spp.	feral, domestic, animals, (human)	0	?	?	?	acute enteritis
Klebsiella pneumoniae (f)	human	0	?	?	low	enteritis (occasional)
Pseudomonas aeruginosa (f)	human	0	?	?	low	gastroenteritis (occasional)
Plesiomonas shigelloides	human	0	?	?	?	diarrhoea
Enterotoxogenic *Clostridium perfringens* (f)	human; animals; soil	0	spores v.p.	?	?	diarrhoea
Francisella tularensis	rodents, animals	0	?	?	?	mild or influenzal, febrile, typhoidal illness

Table 1.1 Continued.

Infection Category/ Pathogen	Major Reservoir	(b)	(c)	(d)	(e)	Clinical syndrome
<u>FAECAL-ORAL</u> / VIRUSES						
Enteroviruses			(Refer to original text)			<u>of</u> <u>enteroviruses</u> : aseptic meningitis, respiratory infection rash, fever
. Poliovirus	human	0		low	high	paralysis, encephalitis
. Coxsackievirus A	human	0		low	high	herpangina, paralysis
. Coxsackievirus B	human	0		low	high	myocarditis, pericarditis, encephalitis, epidemic pleurodynia, transient paralysis
. Echovirus	human	0		low?	high	meningitis
. types 68-71	human	0		low?	high?	encephalitis, acute haemorrhagic conjunctivitis
Hepatitis A	human	0		low	high	infectious hepatitis type A
Hepatitis non-A, non-B	human	0		low	high?	hepatitis type non-A, non-B
Norwalk and other parvovirus-like agents	human	0		low	high?	epidemic, acute non-bacterial gastroenteritis
Rotavirus	human; animals	0		low?	high?	non-bacterial, endemic, infantile gastroenteritis; epidemic vomiting and diarrhoea
Influenza A	human; animal	0		low	?	influenza

Table 1.1 Continued.

Infection Category/ Pathogen	Major Reservoir	(b)	(c)	(d)	(e)	Clinical syndrome
FECAL-ORAL / PROTOZOA						
Giardia lamblia	human; monkeys	0	3 m	low	high	giardiasis - mild, acute or chronic diarrhoea
Entamoeba histolytica	human; feral; primates, domestic animals	0	20 d	low	medium	amoebiasis (amoebic dysentry)
Balantidium coli	human; swine; feral primates	0	1 m?	low?	medium?	balantidiasis (balantidial dysentry)
FECAL-ORAL / HELMINTHS[g]						
Ascaris (N)	human	9 d	several y	low	high	ascariasis (roundworm infection.)
Ancylostoma (N)	human	7 d	20 w	low	high	hookworm infection
Trichuris (N)	human	3 w	1.5 y	low	high	trichuriasis (whipworm infection.)
Trichostrongylus (N)	human; herbivors	?	?	low?	?	trichostrongyliasis
Taenia (C)	human (cattle, swine - intermediate hosts)	8 w	2 y	low	?[h]	taeniasis (tapeworm infection)
Diphyllobothrium (C)	human; animals (copepod and fish- intermediate hosts)	4 w	life of fish	low	?	diphyllobothriasis (broad fish tapeworm infection)
Clonorchis (T)	human; animals (snail and fish - intermediate hosts)	3 m	life of fish	low	?	chlonorchiasis (Chinese liver fluke infection)
Fasciolopsis (T)	human; swine; dogs (snail and aquatic plants - intermediate hosts)	10 w	?	low	?	fasciolopsiasis (giant intestinal fluke infection)
Paragonimus (T)	human; animals (snail and crabs, crayfish - intermediate hosts)	4 m	life of crab crayfish	low	?	paragonimiasis (Oriental lung fluke infection)
Fasciola (T)	human (snail and acquatic plants, sheep - intermediate hosts)	?	?	low?	?(i)	fascioliasis (sheep liver fluke infection)

Table 1.1 Continued.

Infection Category/ Pathogen	Major Reservoir	(b)	(c)	(d)	(e)	Clinical syndrome
WATER-BASED / BACTERIA						
V. cholerae	aquatic environment	0	30 d	high	low	cholera (O1 serovars) or cholera -like infection (non-O1)
V. parahaemolyticus	aquatic environment	0	?	high?	low	gastroenteritis
V. fluvialis	aquatic environment	0	?	high?	low	gastroenteritis
lactose-poritive *Vibrio*	aquatic environment	0	?	?	?	pneumonia and septicaemia
Aeromonas hydrophilia (f)	aquatic environment	0	?	?	?	acute diarrhoea
WATER-BASED / HELMINTHS (g)						
Dracunculus medinensis (N)	human; feral animals (via *Cyclops* vector)	several w.	life of copepod	low?	high (j)	dracontiasis (Guinea worm infection)
Spirometra mansoni (C)	domestic, feral animals (via copepod vector)	several w.	life of copepod		low?	sparganosis (plerocercoid tapeworm larvae infection)

LEGEND

(a): Table compiled from summary of McNeill, 1985). (b): Latent period: minimum time required for infectivity (of humans): v.p. = very persistent, sev. = several, d = days, w = weeks, m = months, y = years. (c): Persistence: expected maximum survival time of infective stage at 20-30 °C: v.p. = very persistent; sev. several; d=days; w=weeks; m=months; y=years. (d): Median infective dose: High (>10^6 organisms); medium (med. - 10^4); low (<10^2). See also Table 1.3. (e): Infection transmission potential: predicted from latency, persistence, median infective dose. (f): See Table 1.2. (g): N= nematode; C=cestode; T=trematode. (h): Higher when sewage irrigation, pastures, fodder used for animal feed and amongst raw meat eaters. (i): Higher in sheep raising areas. (j): High in endemic regions. ?: Not known.

Table 1.2 Human Pathogenic Micro-organisms Potentially Water-contact Transmitted

PATHOGEN	CLINICAL SYNDROME
BACTERIA	
Pseudomonas aeruginosa	Otitis externa and media; follicular dermatitis (pruritic pustular rash)
Aeromonas hydrophila	Wound and ear infections, septicaemia, meningitis, endocarditis, corneal ulcers
Aeromonas sobria	Wound and ear infections
Halophilic vibrios (including *V. parahaemolyticus*, *V. alginolyticus*, lactose positive *Vibrio*)	Wound and ear infections, conjunctivitis, salpingitis, pneumonia, septicaemia
Staphylococcus aureus	Wound and skin infections
Mycobacterium marinum	Skin infection ('swimming pool granuloma')
Mycobacterium ulcerans	Skin infection (progressive subcutaneous ulceration)
Leptospira interrogans	Leptospirosis (Weil's disease - jaundice, haemorrhages, aseptic meningitis)
Klebsiella pneumoniae	Pneumonia, bacteremia
Legionella spp.	Legionellosis (Legionnaires' disease)
Clostridium perfringens	Wound infection - gas gangrene
Pseudomonas pseudomallei	Meliodosis (glanders-like infection)

Table 1.2 Continued

PATHOGEN	CLINICAL SYNDROME
VIRUSES	
Adenovirus	Pharyngoconjunctivitis (swimming pool conjunctivitis); respiratory infection
Adenosatellovirus	Associated with adenovirus type 3 conjunctivitis and respiratory infection in children, but aetiology not clearly established
PROTOZOA	
Naegleria fowleri	Primary amoebic meningoencephalitis (PAME)
HELMINTHS	
Schistosoma spp. (via snail intermediate host)	Schistosomiasis (bilharzia)
Avian schistosomes (*Trichobilharzia*, *Austrobilharzia* via snail intermediate host)	Schistosome dermatitis (swimmer's itch)
Ancylostoma duodenale	Hookworm infection
Necator americanus	Hookworm infection

(from McNeill, 1985).

Table 1.3: Human Minimum Infective Dose (MID) for some Bacterial, Viral, and Protozoan Pathogens

Pathogen	Route	MID Range (No. organisms)	Ref.
BACTERIAL			
. *Vibrio cholerae*	oral	3-10	1,2
serovar Ogawa	oral	10^3-10^6	3
serovar Inaba	oral	10^4 (b); 10^8	3
. *Campylobacter jejuni*	oral	500	4
. *Shigella* spp.	oral	10^2-10^3	5
S. flexneri, 2a	oral	10^2-10^6 (c)	1,6,7
S. dysenteriae, 1	oral	10^3	8
. *Salmonella* spp.	oral	10^2-10^8	9,10,11,12
S. typhi	oral	3-5	1
S. meleagridis	oral	10^7	15
. Enterotoxigenic *E. coli*	oral	10^6-10^{10}	16,17,18
. *Clostridium perfringens*	oral	10^9	19,20
. *Yersinia enterocolitica*	oral	10^9 (c)	21

Table 1.3 Continued

Pathogen	Route	MID Range (No. organisms)	Ref.
VIRAL			
. Poliovirus 1 (SM)	oral	2-20 PFU (d)	22,23,24
2 (P712)	oral	100 TCD_{50} (d)	25
3 (Fox)	oral	<=10 TCD_{50} (d)	9,26
. Coxsackievirus A21	nasal	<=18 TCD_{50} ; 20 ID_{50} (d)	9,27
. Adenovirus	nasal	<=150 TCD_{50} ; 10^3 ID_{50} (d)	9,28
. Adenovirus 8	opthalmic	80 TCD_{50}	29
. Adenovirus 27	opthalmic	32 TCD_{50}	30
. Influenza virus	nasal	5-100 ID_{50}	9
		<=790 TCD_{50}	31
. Hepatitis virus type A	oral	(e)	32,33
. Norwalk agent	oral	(e)	34
PROTOZOAN			
. *Entamoeba coli*	oral	$10-10^4$	36
. *Giardia lamblia*	oral	$10-10^6$	37

LEGEND:

(a) Dose range represents lowest and highest medium doses.
(b) Buffered in $NaHCO_3$
(c) Circum.
(d) PFU - Plaque Forming Units; TCD_{50} - 50% Tissue Culture Infective Dose; ID_{50} - 50% Infective Dose.
(e) 75% infected from faecal fitrates.

(from McNeill, 1985).

Champlain, Vermont. After the occurrence of several similar cases, two throat and two rectal swabs were obtained from each camper and counsellor. From a total of 132 specimens, virus was isolated from 36 specimens from 15 boys. A sample of swimming water collected shortly after swab colleection yielded virus.

In 1974, Denis et al. (1974) reported that five children experienced coxsackievirus A16 infection some days after swimming in a lake. Shortly after the outbreak, samples of water were taken from the swimming area of the lake. These yielded E. coli (at 50 to 1000 colonies per 100 mL of water), Streptococcus D (at 30 to 120 colonies per 100 mL of water), P. aeruginosa (at 150 to 450 colonies per 1000 mL of water), as well as coxsackievirus A16. Unfortunately, water samples are not always available at the time of exposure during outbreaks, and therefore, it is necessary to employ data collected from samples as soon as possible after exposure.

Rosenberg et al. (1976) described a shigellosis outbreak which occurred in Iowa, on the Mississippi River, during the summer of 1974. The geometric mean of the fecal coliform count for the river in August was 17,500 organisms per 100 mL of water, more than eight times the accepted federal limit of 200 per 100 mL of water (National Technical Advisory Committee, 1968). Interestingly, a significant association ($p<0.0001$) between diarrheal illness and swimming was found in a retrospective survey of 60 families who had camped in a park beside the river. The

attack rate for campers who ingested water while swimming was 18 per cent, whereas for those who did not ingest water, the attack rate was 2 per cent. It was suggested that shigellosis could be caused by the ingestion of only 10 to 100 organisms.

Craun (1979) stressed the importance of routine monitoring of recreational waters and corrective measures undertaken to ensure safe conditions during periods of peak demand. He described an outbreak which took place in 1976 in Crater Lake National Park, U.S.A., where 1000 cases of enteropathogenic E. coli were recorded.

Canadian data for waterborne disease, in 1976, was outlined by Todd (1981). Municipal water supplies were contaminated more often than were semi-public systems (i.e. systems which have their own water supplies available for public utilization, such as industry and hotels). During 1976, there were two single cases of Vibrio parahaemolyticus infecting the wounds of people who swam in the sea off the coast of British Columbia. Also during 1976, Cercaria catascopii - the parasite which causes swimmer's itch - was responsible for several hundred cases of the affliction in summer campers and cottagers on the shores of lakes in Southern New Brunswick.

1.5 Recreational water quality indicators

Several of the more widely held views regarding water quality indicators are presently issues of considerable

debate. Researchers have proposed a wide variety of potential bacterial recreational water quality indicators. Further investigations of these topics will be outlined below.

The traditional use of total coliforms as recreational water indicators in the United States during the 1950's gave way to the current use of fecal coliform indicators during the 1960's (Dufour, 1984). Gallagher and Spino (1968) also acknowledged that a drawback in the use of total coliforms is that they may originate from sources other than fecal pollution. In addition, it was revealed that many investigators have reported that fecal coliforms may arise from human and warm-blooded animal pollution, and they are considered to be more directly indicative of enteric pathogens. Despite these widely held beliefs, the investigators detected little correlation between total coliform and fecal coliform densities and probable salmonellae isolation in stream surveys. Gallagher and Spino concluded that low values of total coliforms and fecal coliforms provide an insufficient basis on which to designate recreational waters as being bacteriologically safe from pathogens.

Traditionally held concepts were further questioned by Feachem (1975). He took issue with the conclusions of Geldreich and Kenner (1969) that a aquatic fecal coliform: fecal streptococci ratio of less than 0.7 usually indicates contamination from domestic farm animals, and that ratios greater than 4 indicate human contamination. Feachem found

that differential die-off rates of fecal coliforms and fecal streptococci invalidate the use of the ratio to distinguish between human and non-human sources of pollution. He believes that a predominantly human source should display an initially high ratio (greater than 4) which should then fall. In contrast, a non-human source should exhibit an initially low ratio (less than 0.7) and subsequently rise.

Cabelli (1977) listed the following criteria for consideration in the selection of the best recreational water quality indicator:

1. The indicator should be consistently and exclusively related to the source of the pathogens.

2. The indicator must be present in adequate numbers to permit an "accurate" density estimate whenever the level of each of the pathogens is such that the risk of illness is not acceptable.

3. The indicator should approach the resistance to disinfectants and environmental stress, including toxic materials, of the most resistant pathogen potentially found at significant levels in the source.

4. The indicator should be quantifiable in recreational waters by fairly easy and inexpensive techniques and with great accuracy, precision, and specificity.

Cabelli (1977) considered the following as potential indicators: total coliforms, fecal coliforms, *E. coli*, *Klebsiella* sp., *Enterobacter - Citrobacter* sp., enterococci, *Clostridium perfringens*, *Candida albicans*,

bifidobacteria, enteroviruses, coliphage, Salmonella sp., Shigella sp., P. aeruginosa, A. hydrophilia, and V. parahaemolyticus. After evaluating the choices in relation to the above criteria, he finally favoured the use of E. coli and the enterococci as recreational water quality indicators. The discussion was based on data derived from an epidemiological survey which revealed that:

1. Both E. coli and the enterococci were consistently and specifically associated with the source of the pathogens, which was human fecal wastes.
2. Both the organisms were present in the water in sufficient density to index the low rates of the mild types of gastrointestinal symptoms reported.
3. Both organisms survive transport from the source (the effluent outfall) to the target (the bathing beach) well enough to provide a fairly good correlation to the symptoms observed at the beaches. Presumably the symptoms are caused by the sewage pathogens.
4. Quantitative techniques for both bacteria present no problem for technical staff.

Cabelli (1978) outlined several microrganisms which have been seriously considered as recreational water quality indicators. He also considered their sources and potential uses (Table 1.4). All except for the last four organisms have been considered as potential indicators of contamination of fecal wastes of warm-blooded animals, since relatively large numbers of them were found in municipal sewage wastes.

Table 1.4. Potential Recreational Water Quality Indicators

Indicator	Significant Source	Potential Use
Coliforms	F S I R A	S
Escherichia coli	F S	P F S A
Klebsiella sp.	S I R A	P S N
Enterobacter sp.	S I R A	S
Citrobacter sp.	S I R A	S
Fecal coliforms	F S I R A	F[d] S
Enterococci	F S c	F S A D
Clostridium perfringens	F S c	F S D
Candida albicans	F S	P F S
Bifidobacteria	F S	F S A D
Enteroviruses	F S	P
Salmonella sp.	F S	P
Shigella sp.	F S	P
Coliphage	S[d] c	S
Pseudomonas aeruginosa	S I R A	P S N
Aeromonas hydrophila	S I R A	P S N
Vibrio parahemolyticus	A	P N

Legend:

a - relative to other sources

F - feces of warm-blooded animals
S - sewage
I - industrial wastes
R - run-off from uncontaminated soils
A - fresh and marine waters

b - Potential use

P - pathogen
F - fecal indicators
S - sewage indicator
A - separation of human from lower animal sources
D - proximity to fecal source
N - indicator of nutrient pollution

c - insufficient information
d - questionable

(from Cabelli, 1978).

Dufour (1984) also prepared a comprehensive summary of the ideal characteristics of the bacterial indicators of recreational water quality (Table 1.5).

Staphylococcus aureus and total staphylococci were promoted by Evans (1977) as good indicies for bathing waters since they constitute a major component of the bacterial flora of both recreational waters and swimming pools which have a high swimmer load. In addition, he thought that the total staphylococci may be the most appropriate of the two mentioned. This belief is shared by Brown (1983) who recommended the use of total staphylococci as recreational water quality indicators, along with fecal coliforms.

Evison (1979) indicated that in order to ascertain swimmers' risk of contracting eye, ear, nose, throat, or skin infections, *S. aureus* and *P. aeruginosa* should be enumerated. His reasoning was based on the fact that fecal coliforms alone would be related only to the incidence of gastrointestinal infections. Futher studies were deemed necessary.

Interestingly, it was Dutka (1979) who emphasized the need for multiple indicator systems for water quality studies, in order to ascertain potential health hazards.

Recently, Cabelli (1982; 1983) has favoured the enterococci as recreational water quality indicators of enteric disease caused by water polluted by sewage. Cabelli (1983) revealed that if bacteria do not adequately reflect the presence of the three most relevant viral pathogens

Table 1.5 Ideal Characteristics of Bacterial Indicators of Fecal Contamination

Ideal Characteristics	Bonde 1966	Scarpino 1971	Dutka 1973	Cabelli 1977	Barrow 1981
1. Present where pathogens are	X	X	X	X	X
2. Unable to grow in aquatic environments	X	X	X		X
3. More resistant to disinfection than pathogens	X		X	X	X
4. Easy to isolate and enumerate	X	X	X	X	X
5. Applicable to all types of water		X			
6. Not be subject to antibiosis	X				
7. Absent from sources other than sewage or be exclusively associated with sewage				X	X
8. Occur in greater numbers than pathogens	X			X	X
9. Density of indicator should have direct relationship to degree of fecal contamination		X			
10. Indicator density should corrrelate with health hazard from a given type of pollution				X	

(from Dufour, 1984).

(hepatitis A, the Norwalk-like viruses, and the human rotavirus - due to the different disinfection and transport survival charcateristics), then the male-specific, single stranded RNA and DNA coliphages, f-2 (MS-2)and f-1 (Fd) should be considered optimal. This is particularly true for the f-1 (Fd) coliphages due to its marked chlorine resistance (Cabelli, 1983; McBride, 1979). Cabelli (1983) emphasized the benefit of exploring enumerative and concentration methods for the two phages.

Interestingly, an international group of researchers (Akin et al., 1983) suggested that fecal strepococci might prove to be a useful indicator for recreational waters when estimating the virucidal efficiencies of water treatment processes.

At the present time, both American and Canadian officials in the Province of Ontario are considering the possibility of using E. coli as the recreational water quality indicator. However, the discussions have not come to a final conclusion.

1.6 Recreational water quality criteria

1.6.1 Debates regarding the need for recreational water quality criteria.

Whether or not to employ recreational water quality guidelines has been a subject of much world-wide debate, and there is every reason to suspect that the issue will

remain controversial for some time to come.

Shuval (1975) noted the limited amount of dose response data for epidemiological studies of swimming-related illness. This makes the development of a rational bacterial standard difficult in his opinion. Rather, Shuval (1975) favours a direct virus standard in preference to a bacterial standard because of the prolonged survival possibilities and pathogenic aspects of viruses. He proposed a microbial standard of the absence of enteric viruses in 1000 mL of marine waters, along with the reduction of fecal microbes originating in sewage to the lowest possible level.

Most people would favour the use of recreational water quality criteria (Cabelli _et al_., 1975). However, Cabelli _et al_. also acknowledged that many communicable diseases acquired from swimming are neither fatal nor reportable, and that most of them can be transmitted by routes other than recreational ones.

A very prominent critic opposed to the employment of microbial criteria for bathing waters is the British investigator, Moore (1975). He suggested that the British policy of classification of bathing waters by permissible median and 90-percentile levels for a variety of bacteria is both simplistic and spurious. This was based upon the complexity of pollution patterns, as well as the lack of adequate proof to link the risk of infectious disease with the degree of contamination by sewage in bathing waters. Moore firmly maintains that:

1. Bathing beaches cannot be adequately classified in terms of coliform or fecal coli (_E_. _coli_) count.

2. No good evidence exists for a quantitaive relationship between _E_. _coli_ counts and health risks.

3. Allocation of resources to ensure conformity to a particular standard cannot be justified on a public health basis.

Furthermore, Moore states that microbial standards for bathing water are irrelevant to public health. He favours investigations which focus on the development of improved sewage disposal schemes.

Barrow (1981) tends to agree with their British contemporaries. He suggested that it would be almost impossible to develop meaningful universal criteria for bathing water. This is because he felt that bathing applies to many different waters, in many varying ways, and because customs vary with geography, climate, populations, and other lifestyle factors. He emphasized that the risk of contracting serious disease from swimming is minimal, whether or not swimmers are subject to more afflictions than non-swimmers. He implied that it would be difficult to prove epidemiologically that sporadic virus infections may be waterborne. He supports the need for satisfactory aesthetic standards in accordance with the public health attitude that fecal microbial pollution should be as low as feasibly possible. As an example, he noted that _E_. _coli_ counts in recreational waters should be considered highly

satisfactory if the counts are consistently less than 100 per 100 mL of water, and that counts exceeding 1000 per 100 mL of water be designated as unsatisfactory (Barrow, 1981; World Health Organisation, 1975). Barrow also suggested that a standard based on the absence of salmonella in 1 L of water is both unscientific and illogical.

A recently convened international study group (Atkin et al., 1983) advocated a multi-disciplinary team approach to evaluate the public health significance of viruses in water.

Yet another group of British researchers (Jones and White, 1984) revealed that the United Kingdom communicable disease statistics do not reflect significant levels of waterborne disease from surface water exposure. However, Jones and White admitted that no comprehensive studies of health risks acquired from freshwater exposure have been done in the United Kingdom. They also noted that polluted freshwater presents more potential for health risks than does seawater, because of the extended bacterial survival times associated with freshwater.

Clearly, the subject of the need for microbial recreational water quality guidelines is unresolved and merits further epidemiological and microbiological investigation.

1.6.2 Historical development of microbiological guidelines for recreational waters

The development of total coliforms and fecal coliforms as the microbial indicators for American bathing waters was described by Dufour (1984). It was Scott (1932) who developed a classification scheme based on a four-fold grouped frequency distribution of bacterial count levels in water samples. The groups were 0-50, 51-500, 501-1000, and greater than 1000 total coliforms per 100 mL of water (Dufour, 1984; Scott, 1932). Scott's decisions were formulated from the findings of a survey of the Connecticut shorelines. The study revealed that 92.8 per cent of the water samples contained less than 1000 total coliforms per 100 mL of water. A sanitary survey of the shoreline conducted to determine the extent of pollution also revealed that only 6.9 per cent of the shoreline displayed particularly poor water quality (Dufour, 1984; Scott, 1932). On the basis of these results, Scott (1932) suggested that total coliform densities below 1000 per 100 mL of water were likely to be acceptable for bathing waters (Dufour, 1984; Scott, 1932). At that time, there was no epidemiological information to support this conclusion. However, this proposal was adopted by the American Public Health Association in 1943, and subsequently received widespread acceptance by Americans (Dufour, 1984).

In 1963, an American federal committee suggested that fecal coliforms were a better microbial recreational water quality indicator than total coliforms (Dufour, 1984; National Technical Advisory Committee, 1968). The committee

examined the earlier studies of Stevenson (1953) in order to set the guidelines (Dufour, 1984). Stevenson detected significant increases in swimming-related illness at total coliform densities in the region of about 2,300 to 2,700 organisms per 100 mL of water. The committee estimated the ratio of fecal coliforms to total coliforms in the mid-1960's, on the same section of the Ohio River that Stevenson (1953) investigated earlier in the 1940's and 1950's (Dufour, 1984). Because the ratio was approximately 18 per cent, they assumed that a detectable health effect would be found at a fecal coliform density of 400 organisms per 100 mL of water. In order to avoid detectable health problems, the committee introduced a protective safety factor and set the federal American standard at 200 fecal coliforms per 100 mL of water (National Technical Advisory Committee, 1968; Dufour, 1984). Therefore, their choice was based upon very little supportive epidemiological and microbiological evidence, and it catalyzed a series of scientific debates.

1.6.3 American microbial guidelines

Presently, the United States Environmental Protection Agency has outlined the following microbial criteria for recreational bathing waters:

> Based on a minimum of five samples taken over a 30-day period, the fecal coliform bacterial level should not execeed a log (geometric) mean of 200 per 100 mL, nor

should more than 10 per cent of the total samples taken during any 30-day period exceed 400 per 100 mL (U.S. Environmental Protection Agency, 1976).

1.6.4 Microbial guidelines in Ontario, Canada

In the Province of Ontario, Canada, the current microbial recreational water quality guideline is a fecal coliform geometric mean density of 100 per 100 mL of water, where at least ten samples per month, and ten samples per location were recommended (Ontario Ministry of the Environment, 1978). A potential health hazard is considered to exist if this guideline is surpassed. In addition, if the total coliform geometric mean density for a series of samples exceeds 1000 per 100 mL of water (based on the same sampling frequency as that for fecal coliforms), then a potential health hazard is considered to exist for recreationalists. If microbial pathogens can be enumerated and isolated frequently from recreational waters, then there is also evience that a potential health hazard may exist.

It is apparent that many expressions for listing guidelines are used, such as: mean, geometric mean, log mean, median, average, etc. (McNeill, 1985). However, after data normalization through a logarithmic transformation, the arithmetic mean is the best measure of central tendency (i.e. the arithmetic mean of the logarithmically transformed data). This mean bears a direct relationship

with the geometric mean of the original data (i.e.: barring rounding error, the values should be the same; A. Burgher, pers. comm.), and the calculations performed use the following relationship:

$$\log(x) = (\log(x1) + \log(x2) + \ldots + \log(xn))/n$$

$$\log(x) = \log\,(x1 * x2 * .. * xn)^{1/n}$$

Therefore,

$$\text{"Geometric mean"} = x = \exp((\log(x1) + \log(x2) + \ldots + \log(xn))/n).$$

Although Canadians generally refer to a geometric mean guideline, the specific calculation performed is the arithmetic mean of the logarithmically transformed data (L. Vlassoff and R. Tobin, personnal communications). The same appears to be true of the American studies when they refer to the geometric or logarithmic means (Bordner _et al._, 1978) As a result, this study uses the term "geometric mean" in this context.

It has been suggested that the ratio of fecal coliforms to fecal streptococci may distinguish human from non-human waste (Geldreich, 1969). If the ratio of the geometric means exceeds 4 at the point of discharge, then the source is likely to be human. In contrast, if the ratio

is less than 0.7 at the point of discharge, then the source is probably non-human. Many environmental conditions may influence this ratio, so it is essential that it be applied with care (Ontario Ministry of the Environment, 1978). For the ratio is considered to be reliable, the fecal coliform density should exceed 100 per 100 mL of water (Ontario Ministry of the Environment, 1978). However, it may be wise to take into consideration the comments made by Feachem (1975), outlined in section 1.5).

Recent studies revealed that bacteria such as Pseudomonas sp. and Staphylococcus sp. might prove to be useful aetiological indicators of the risk of eye, ear, nose, throat, and skin infections (Ontario Ministry of the Environment, 1978).

1.6.5 Canadian microbial guidelines

The Canadian federal government recommends that the fecal coliform concentration should not exceed 200 per 100 mL for recreational waters (The Ministry of National Health and Welfare, 1983). Health hazards may be deemed to exist if this value is exceeded (The Ministry of National Health and Welfare, 1983). Recreational waters were defined as natural waters used mainly for swimming and other water contact sports, and were also applicable to such activities as boating, fishing, and other sports involving less frequent body contact with the water. Recreational use represented any activity involving intentional body immersion,

including the head, in water, or where such immersion is probable (e.g water skiing).

The specific guidelines listed for fecal coliforms were:

> The geometric means of not less than five samples taken over a 30-day period should be less than 200 fecal coliforms per 100 mL of water. Resampling should be performed when any sample exceeds 400 fecal coliforms per 100 mL of water (The Ministry of National Health and Welfare, 1983).

A summary of the maximum limits for total and fecal coliforms was also provided by the Canadians (The Ministry of National Health and Welfare, 1983, - reproduced in Table 1.6).

The Canadian publication (The Ministry of National Health and Welfare, 1983) recommended that data for fecal streptococci may be useful when combined with fecal coliforms to ascertain the type and extent of surface water pollution. Occassional monitoring for total coliforms was considered to be of historical value in generating long-term trends.

Should any of the following pathogens be isolated consistently from recreational waters irrespective of the fecal coliform count, then a possible health hazard may exist: _P. aeruginosa_, _S. aureus_, _Shigella_ sp., _Salmonella_ sp., and polio or other enteric viruses (The Ministry of

Table 1.6 Summary of Maximum Limits of Coliforms in Primary Contact Recreational Waters Presented by Various Agencies

AGENCY(a)	SAMPLING REGIME	TOTAL COLIFORMS	FECAL COLIFORMS	OTHER
1. (U.S.) National Technical Advisory Committee	Not less than 5 samples taken over not more than a 30-day period	-	<=200/100mL, nor shall more than 10% of the samples exceed 400/100mL	-
2. Province of British Columbia	Not less than 5 samples taken over not more than a 30-day period	-	Running geometric mean <=200/100mL, nor shall more than 10% of the samples exceed 400/100mL	
3. Inland Waters Directorate Department of the Environment	-	<=500/100mL	<=200/100mL	-
4. Alberta Environment	Not less than 5 samples taken over not more than a 30-day period	Geometric mean <=1000/100mL	Geometric mean <=200/100mL	-
5. Ontario Ministries of Health, Environment	At least 10/30 days <u>Staphylococcus</u>	Geometric mean <=1000/100mL	Geometric mean <=100/100mL	Fecal streptococci <u>Pseudomonas</u>

AGENCY(a)	SAMPLING REGIME	TOTAL COLIFORMS	FECAL COLIFORMS	OTHER
6. Committee of the Great Lakes Upper Mississippi River Board of State Sanitary Engineers	-	-	Geometric mean <=200/100mL. No sample to excedd 1000/100mL	Fecal streptococcus Pseudomonas
7. World Health Organization	-	-	*E. coli*<=1000/100mL	-
8. U.S. Environmental Protection Agency	Not less than 5 samples taken over not more than a 30-day period	-	Geometric mean <=200/100mL nor shall more than 10% of the samples exceed 400/100mL	-
9. Saskatchewan Environment	Not less than 5 samples taken over not more than a 30-day period	Geometric mean <=1000/100mL	Geometric mean <=200/100mL	-
10. Manitoba Clean Environment Commission	Not less than 5 samples per month	Median <500MPN/100mL	Median<200MPN/100mL	-

LEGEND

(a) See text for references.

(based on The Ministry of National Health and Welfare, 1983).

National Health and Welfare, 1983). Sanitary surveys of watersheds were advocated and it was suggested that they include:

1. Investigation of the risk of inadequately treated sewage, fecal matter, or other hazardous substances entering the water.

2. Knowledge of all outfalls or any drainage that may contain sewage in the area, particularly upstream.

3. On-site inspections by competent observers or inspectors who are familiar with the area.

4. It would be advisable to establish a reporting mechanism to ensure that the appropriate authorities are informed if a municipal, private, or industrial water treatment installation is discharging waste that jeopardizes the water quality of bathing areas - such discharges could be caused by plant malfunctions, breakdowns, overloading or bypassing.

Microbial pathogens were also discussed in the Canadian publication (The Ministry of National Health and Welfare, 1983). For example, monitoring for <u>Candida albicans</u> was recommended to commence when deemed necessary, in order to determine its prevalence and health implications. In the case of <u>P. aeruginosa</u>, it was suggested that information be used to supplement the results of sanitary surveys of recreational waters, and that a health hazard be considered to exist when these bacteria can be enumerated and isolated frequently in swimming areas. The recommendations for <u>Salmonella</u> sp. were

similar insofar as they should be used as an aid in interpretation of the results of microbial and sanitary surveys, and that a health hazard be deemed present upon consistent bacterial isolation from a bathing area. Sampling for Shigella sp. was advocated when there is epidemiological of other evidence or its presence in the water. The same criteria were listed for S. aureus. For viruses, occassional monitoring was suggested in order to determine their distribution and relationship to disease incidence.

It was recommended that health authorities monitor epidemiological data for their recreational area, as well as report waterborne infections (The Ministry of National Health and Welfare, 1983). Poor recreational water quality would be deemed to exist if community reports of waterborne infections arose, or if the morbidity or mortality data revealed that possible sources of infection could be present in, or transmitted from, recreational waters.

It was also proposed that a maximum geometric mean of not less than five samples taken over a thirty-day period at 200 fecal coliforms per 100 mL of water probably corresponds to approximatelly 0.12 to 1.5 per cent chance of contracting gastrointestinal illness, according to available epidemiological data (The Ministry of National Health and Welfare, 1983).

No other numerical maximum limits were listed for microbial indicators or pathogens.

The subject of sampling procedure is an important

issue in setting bacterial standards. In the same document described above, the Ministry of National Health and Welfare (1983) outlined how sampling should be performed. Routine monitoring was recommended which included at least five samples per month from each area. More frequent sampling was suggested for beaches with high bather loads (the water should be sampled during the period of maximum bather load at the point of maximum beach use).

The Canadian publication (Ministry of National Health and Welfare, 1983) suggested that sampling on weekends and holidays must be included, especially at such times when maximum pollution is expected (e.g. during sewage by-passing, after heavy rainfall, or during high on-shore winds which stir up the sediment). It was also suggested that samples from estuarine and marine swimming areas be collected at high, slack, and low tides, in order to constrain the patterns of cyclical water quality. When any water sample surpassed 400 fecal coliforms per 100 mL of water, immediate sampling was deemed necessary to reveal possible sources of contamination. Samples collected from representative areas at each location (including areas with highest bather load, upstream areas where drains discharge, septic tank effluent, and runoff from refuse dumps) should be analyzed. Sampling should be completed either by hand (in which case, a depth of 15 to 30 cm was advocated for water 1.0 to 1.5 m deep), or by using various devices.

The same publication (The Ministry of National Health and Welfare, 1983) warned that recreational areas should

not be developed in regions with excessive growth of aquatic plants unless measures are taken for their removal. For waters used for total body contact, pH ranges of 6.5 to 8.5 were considered appropriate, but values from 5.0 to 9.0 were considered to be acceptable if the water has a very low buffering capacity. The upper limit recommended for temperature was $30^{o}C$, and extensive periods at temperatures under $15^{o}C$ were listed as being capable of causing fatality or extreme stress without protective aquatic clothing. Waters should be free of substances attributable to wastewater or other discharges, in quantities which would interfere with species of aesthetic value. A limit of 50 on the Jackson Turbidity scale was proposed. The water should be clear enough to see a Secchi disc at a minimum of 1.2 m. Furthermore, water colour should not be so intense as to impair underwater visibility in swimming areas. Finally, it was recommended that oil or petrochemicals should not be present in quantities that:

1. Can be detected as a visible film, sheen, or discolouration on the surface.
2. Can be detected by odour.
3. Can form deposits on shorelines and bottom sediments which can be seen or smelt (The Ministry of National Health and Welfare, 1983; International Joint Commission, 1977).

1.6.6 European Economic Communities (EEC) microbial guidelines

The European Economic Community (EEC) have issued a directive on bathing water quality (Commission of the European Communities, 1976). Gameson (1979) comments on this directive. The directive applied to all running and still freshwaters, and to seawater in which bathing is permitted by the authorites, or traditionally practised. The directive suggests that samples should be collected at places where the daily average bather load is highest, 30 cm below the surface of the water, and should begin two weeks prior to the bathing season. Gameson (1979) commented on the difficulty of interpreting the directive (e.g. the definition of highest average bather load). The microbial criteria for bathing waters are outlined in Table 1.7. Various criteria for physico-chemical parameters were also outlined in the directive.

1.6.7 A summary of microbial guidelines for various countries

A summary of some microbial guidelines for various countries is presented in Table 1.8.

1.7 Summary and conclusion

In summary, it is apparent that microbial pollution of recreational waters can arise from several sources, including: animal, human, agricultural, industrial, and

Table 1.7 European Economic Communities (EEC) Microbial Quality Requirements for Bathing Water

PARAMETERS	G*	I**	Min. Smpling. Freq.	Method of analysis and inspection
Total coliforms /100mL	500	20000	Fortnightly (1)	Fermentation in multiple tubes. Subculturing of the positive tubes on a confirmation medium. Count according to MPN (Most Probable Number) or membrane filtration and culture on an appropriate medium such as Tergitol lactose agar, endoagar, 0.4% Teepol broth, subculturing and identification of the suspect colonies. The temperature of incubation varies with testing either total or fecal coliforms.
Faecal coliforms /100mL	100	2000	Fortnightly (1)	
Faecal streptococci /100mL	100	-	(2)	Litsky method. Count according to MPN or filtration of membrane. Culture on an appropriate medium.
Salmonella / 1 litre	-	0	(2)	Concentration by membrane filtration. Inoculation on a standard medium. Enrichment - subculturing on isolating agar - identification.
Enteroviruses PFU/10 litres	-	0	(2)	Concentration by filtration, flocculation or centrifuging and confirmation.

LEGEND:

G = Guide. Conforms to 90% of samples (80% for total coliforms and fecal coliforms) correspond to specifications.

I = mandatory. Conforms if 95% of samples correspond to specifications.

(0) Provision exists for exceeding the limits in the event of exceptional geographical or meteorological conditions.

(1) When samples taken in previous years have produced results which are appreciably better than those in this Annex and when no new factor likely to lower the quality of the water has appeared, the competent authorities may reduce the sampling frequency by a factor of 2.

(2) Concentration to be checked by the competent authorities when an inspection in the bathing area shows that the substance may be present or that the quality of the water has deteriorated.

(from Comission of Eurpoean Economic Communities, 1976).

Table 1.8 Summary of Microbiological Guidelines for recreational Waters (after McNeill, 1985).

WATER TYPE	CONDITIONS	VALUES (a)	COMMENTS
<u>U.S. (FWPCA, 1968)</u>:			
Water designed for recreational use:			
. Primary contact	Log mean (*5 samples in !30 days), max. in 10% samples (30 days)	200 FC 400 FC	Primary contact - intimate contact with water involving considerable risk of ingesting water in quantities sufficient to pose significant health hazard.
. Other than primary contact	Log mean max. in 10% samples	1000 FC 2000 FC	For enhancement of recreational value of waters for recreational uses other than primary contact.
Water not designed for recreational use:			
. General use (secondary contact)	Average Maximum	!2000 FC 4000 FC	
<u>European Economic Community (Council Directive 76/160/EEC - CEC, 1976)</u>:			
Bathing water (both fresh and sea)	80% of TC and FC 90% of FS samples to meet guide values. 95% of samples to meet mandatory values	**Guide and Mandatory** 100, 2000 FC 500, 10000 TC 100, - FS -, 0 Salm. -, 0 Virus	Includes areas where: bathing explicitly authorized or not prohibited and traditionally practised by many. Minimum sampling frequency for FC and TC, fortnightly, reduce to monthly in prevalent years show results better than values given and unlikely to worsen. Commence sampling 2 wks prior to bathing season. Monitor for FS, Salm. (absent/L), Enterovirus (0 PFU/10uL) whenever area suspected (from inspection) to have these or water quality deteriorates.

Table 1.8 Continued

WATER TYPE	CONDITIONS	VALUES (a)	COMMENTS
USSR: All-Union State Standard 17.1.5.02-80 (USSR, 1980):			
Primary contact	maximum	1000 TC	TC - "lactose positive int. bacilli (LIB)". If primary contact values exceeded, test for S. typhi, S. paratyphi, Shigella, staphylococci, enteroviruses. If positive, use of water may continue if TC!10000. Minimum sampling frequency 4 times/month during swimming season. Analyse for EC, enterococci and bacterio phage to define contamination source.
General (boating, sailing)	maximum	10000 TC	
SOUTH AFRICA (Grabow, 1977) :			
Primary contact	maximum	1000 TC	Or absence of undisintegrated faeces.
	log mean	200 EC gp 1	
Not primary contact	log mean	1000 EC gpl	
WHO: (WHO, 1975)			Water classification
Bathing areas	consistently	<100 EC	. Highly satisfactory (bathing area waters)
	consistently	<=1000 EC	. Acceptable
WHO: (WHO/UNEP, 1977) :			
Bathing areas	max. in 10% samples (>=10 consecutive samples in bathing season)	<=1000 EC	Refinement of WHO 1975 criterion above, and 100 EC/100mL criterion to be basis for design of treatment and disposal systems.

Table 1.8 Continued

WATER TYPE	CONDITIONS	VALUES (a)	COMMENTS
New Zealand: Water Pollution Regs. (NZ, 1969)			
Inland waters Coastal waters, Class SB	consistently median	<=1000 TC <=200 FC	Accessible and regularly used waters for public bathing
Australia (Hart, 1974) :		FC Level	Water Classification
Recreational waters		<50	. satisfactory
		50 to 200	. slight pollution
		1000 - 2000	. distinct pollution, water suspect
		>2000	. heavy pollution, water objectionable
ACTION : if 200 FC/100mL approached or exceeded regularly during rec. season, relevant authority should assess possible health risk (e.g. sanitary survey of area and pollution input sources; analyses for pathogenic bacteria and viruses).			
Australia (NH and MRC, 1978) :			
Waters to be used for recreational uses within designated areas	Modified USEPA 1972 (see text)		Because of paucity of valid epidemiological data, no specific recommendation made concerning conc. of micro-orgs. in bathing waters. Such matters remain responsibility of advisory health authority.

LEGEND:

(a): TC = total coliforms/100mL; FC = faecal coliforms/100mL; EC = E . coli /100mL; FS = faecal streptococci/100mL;
Salm. = Salmonella/ 100 mL.
* - not less than, ! - not more than.

(from McNeill, 1985).

vegetative microorganisms. In addition, introduction of microbes from such sources may take place indirectly by such routes as urban and rural stormwater runoff. Clearly, meteorological conditions also play a key role in the transportation and survival of microbes.

At present, recreational waters are being designated microbially polluted primarily on the basis of bacteriological indicator testing which is designed to reflect the presence of potential pathogens.

The microbial guidelines for recreational waters are neither universally consistent, nor are they founded upon firm epidemiological and microbiological evidence. It is unfortunate that sampling and isolation procedures are not precisely and consistently defined, and that there is great ambiguity and misapplication in the literature regarding the statistical proceedures adopted (e.g. type of mean etc.). Utilization of a variety of international guidelines, based upon geometric means, arithmetic means, and medians makes comparisons very difficult.

CHAPTER 2

EPIDEMIOLOGICAL STUDIES OF SWIMMING-RELATED ILLNESS

2.1 Types of studies

Epidemiological studies of swimming-related illness have evolved over time from less complex investigations to studies which generate predictive models of illness. It is this evolution of ideas which is presented and discussed in this chapter.

2.2 Less complex studies

Stevenson (1953) undertook three studies to determine the effects of recreational water quality on swimmers' health at the following locations: 1) on Lake Michigan (a Great Lake at Chicago, Illinois, 2) on the Ohio River (an inland river) at Dayton, Ohio and at a swimming pool (a recirculating pool) in the same area, and 3) on Long Island Sound (a tidal water) at New Rochelle and Mamaroneck, New York. For each study, two bathing areas were chosen based on: 1) substantial differences in bacterial water quality, as revealed by historical records, 2) results from sanitary surveys which indicated that water quality did not fluctuate rapidly, (although changes over a period of days were desirable), 3) locations close to areas having residential populations of 1500 or more families, and 4) swimming areas popular with local residents.

For each study, the population groups selected were of similar socioeconomic levels and they lived in the same geographic area (Stevenson, 1953). A public information campaign was conducted to aquaint people with the study. In the study areas, families were visited to obtain permission for study participation. Participating families were instructed how to complete a calendar record form which was designed to outline daily swimming and illness experience. Follow-up visits to participating households were made two or three times in the swimming season. At the conclusion of the study period, each household was visited and re-visited as needed to ensure record completion. Participating families returned about 80 per cent of the records in usable form, although some did not maintain records on a daily basis. Unfortunately, the bacterial analysis was conducted "at intervals to observe significant fluctuations" - no description was provided of the specific microbial methods.

In each of the studies (Stevenson, 1953), there were 5124, 7520, and 9520 participants, respectively. The respective total incidence rates for nonswimmers per 1000 person-days at each swimming area were: 3.7 at North Beach, Chicago, 5.6 at South Beach, Chicago, 7.4 at Dayton and Bellevue, and 3.3 at new Rochelle and at Mamaroneck. For swimmers, the values were 7.1 at North Beach, Chicago (where the median total coliform count per 100mL of water was determined by the MPN method to be 91), and 8.3 at South Beach, Chicago (where the median water quality was

190 total coliforms per 100mL of water), 8.8 at Dayton and Bellvue (with a median count of 2700 in the river and less than 3 in the Dayton Pool), 5.3 at New Rochelle, and 6.2 at Mamaroneck (with median values of 610 and 253 total coliforms per 100mL of water). The highest total illness incidence observed in the natural bathing water swimming groups was 13.4 per 1000 person-days for South Beach swimmers who swam more than 24 days. Pool swimmers at Dayton displayed a higher incidence value of 32 per 1000 person-days for those who swam 10 to 19 days. This was mainly attributed to a higher incidence of eye, ear, nose, and throat problems related to diving and swimming in close proximity to other persons in a body of water with a lower dilution factor. Pool swimmers had an overall illness incidence of 13.8 per 1000 person-days. The observed three-day (the days were selected based on the desire to compare the health effects of relatively "high" and "low" total coliform densities; the median total coliform density on the three selected "high" days was 2300 versus 43 per 100 mL of water on the three "low" days) incidence rate of 12.2 per 100 South Beach swimmers (versus 8.5 on the "low" days) for illness occurring within a week after swimming was considered to be significant. This result led Stevenson to conclude that swimming in waters containing a logarithmic average coliform density of 2300 per 100mL of water might cause more illness than swimming in waters with lower average densities. However, Stevenson admitted the lack of similar results in his other studies. Based upon

the three investigations, Stevenson indicated that an appreciably higher overall illness incidence might be expected in swimmers versus nonswimmers. Apparently, eye, ear, nose and throat ailments may be expected to represent more than 50 per cent of the overall illness incidence, gastrointestinal problems up to 20 per cent, and skin irritations and other ailments the remainder. Despite the relatively low incidence of gastrointestinal ailments (2.4 per 1000 person-days), swimming in river water (Ohio River) with a median coliform density of 2700 per 100mL seemed to be related to a significant increase in gastrointestinal ailments. River swimmers experienced 32 per cent more gastrointestinal illness than might be expected on the basis of the combined group experiences. Stevenson revealed that some of the strictest existent bacterial quality requirements for natural bathing waters might be relaxed without significant detrimental effects on bathers' health.

Clearly, Stevenson's studies were extensive, novel, valuable, and they prompted further debate and investigation. However, several constructive comments can be levied to pave the way for future investigators. It was rather unfortunate that demographic data were not provided for the study participants, in order to dismiss the possibility of attributing the results to causes other than the bacterial counts. For example, neighbourhood controls were used instead of beach controls to examine the illness rates in nonswimmers. This was a drawback because potential confounders might be associated with a particular beach

(e.g. the food sold by vendors), and these were given no consideration. Furthermore, the possibility of person-to-person transfer within a household existed since the period of follow-up was not precisely defined. Whether follow-up was reported individually by a spokesperson, or all members of a group, was unknown. Thus, it is hoped that the statistical unit of concern was not mixed and that confounding did not result. No precise definition of a swimmer was provided. Unfortunately, Stevenson did not specify the bacteriological procedures and associated sampling regime, nor did he mention the type of statistical testing or levels of significance used. Statistically, the water quality data were not presented consistently - both geometric means and medians are used sometimes interchangeably making comparisons difficult. In summary, the overall study design was difficult to assess due to the vague presentation of the methods employed and results obtained.

During the 1950s, Moore et al. (1959) examined the health risks of bathing in seawater polluted by sewage at several beaches in the United Kingdom (England and Wales). An epidemiological survey was organized to investigate the importance of notified cases of enteric fever and poliomyelitis in bathers. The retrospective survey was actually undertaken only for poliomyelitis information due to the small number of enteric fever cases reported (only four cases were associated with beach activity from 1956 to 1958). The two beaches where a fairly clear association

between bathing and paratyphoid fever was demonstrated, displayed median total coliform counts of over 10,000 per 100mL of water, and both were macroscopically polluted with sewage. For the retrospective survey, medical officers of health near sea areas were asked to obtain a bathing history from patients or their parents, for three weeks prior to poliomyelitis onset in patients (up to 15 years-of-age). Area residents were investigated, but visitors were excluded. At the same time, medical officers of health were asked to select a control from the date of birth on school registers. The control had to meet the following guidelines:

1. The control was not to come from the same household as a case.

2. The control was to be of the same age and sex.

3. The control should preferentially be a resident of the same street (or the same ward or area).

From the control, or the person's parents, the bathing history for the three weeks prior to the onset of illness in the patient was recorded (Moore et al., 1959). Data were presented to compare cases and controls, as well as their bathing histories. Statistical tests to investigate differences between the number of ill swimmers and nonswimmers were considered unneccessary, given the closeness in the values found in the two groups. No evidence was provided for bathing during three weeks prior to the onset of illness - clearly another potential cause of poliomyelitis could be present in the groups examined.

Moore and his collegues concluded that:

1. Bathing in seawater polluted with sewage carries only a negligible health risk, even on beaches that are aesthetically unsatisfactory.

2. The minimal health risk is likely to be associated with chance contact with intact aggregates of fecal material which came from infected persons.

3. Isolation of pathogens from seawater contaminated with sewage is more important evidence of an existing rather than a future health risk.

4. Since a serious health risk is probably not incurred unless the water is aesthetically revolting, public health requirements would seem to be adequately fulfilled by improving grossly unsanitary bathing waters and by preventing the pollution of bathing beaches with undisintigrated fecal matter during the bathing season.

Moore et al. (1959) provide a good description of the methods they used. However, the bacterial sampling regime should have been specified. Furthermore, no precise definition of exposure (in the swimming population) was provided. A child or the parent(s) may have supplied the follow-up information - this discrepancy could introduce additional confounding variables. Importantly, it would appear that several biases may be introduced by the methods of case and control selection and by subject recall (personal communication, C.L.R. Bartlett, H.E. Tillet, and L.F. Bibby). Only a few very serious illness were considered. Illness of lesser importance merits attention,

particularly those associated with the disabillity of staying at home. The retrospective survey cannot take into account the differences encountered in water quality.

A case-control study of swimming related illness was undertaken by D'Alessio et al. (1981). Children up to the age of 15 years who visited a pediatric clinic in Madison, Wisconsin, from June 13th through to September 1st, 1977 were surveyd for the frequency and location of swimming undertaken in the two weeks immediately prior to the clinic visit. Participating children or an accompanying adult completed a questionnaire designed to ascertain: 1) demographic characteristics, 2) the reason for the clinical visit, 3) prominent symptomology in ill subjects, 4) whether the child had been swimming in the two weeks previous to the clinic visit, 5) the frequency of swimming, and 6) the location of the swimming area visited. The study population consisted of 679 controls who were well (derived from routine examinations, immunizations, or treatment of acute minor injuries) and 296 children with enteroviral-like syndromes (children with predominantly febrile illness of the respiratory and/or gastrointestinal tract or central nervous system, or those with undifferentiated febrile illness). A swimmer was defined as a person who made at least one beach or pool visit in the two weeks preceding the clinic visit, whereas a nonswimmer made no visit to the beach or pool. Throat and rectal swabs were obtained from 241 ill patients and 27 well children. Non-polio enteroviruses were isolated from 119 ill and two

well persons, and other viruses were recovered from an additional 13 ill persons. Statistical testing was done using a log-linear model for categorical data analysis. Data were categorized by diagnostic groups, swimming activity, sex, and age. A case of enteroviral illness was defined as the isolation of an enterovirus from a child with compatible illness, because of an insufficient number of paired sera which could establish concurrent infection and illness. Exclusive beach swimmers, from whom non-polioenteroviruses were recovered, dispayed a significantly increased ($p<0.0005$) relative risk (odds ratio estimate 3.41) of enterovirus illness verss well controls. The highest relative risk (10.63) of enterovirus illness was found for children under four years-of-age who were exclusive beach swimmers. No significantly increased risk of enteroviral illness was associated with swimming in pools, exclusively. Children with apparent viral illness, based on clinic results, from whom virus was not isolated did not differ from well controls in the type of swimming exposure (either beaches or pools) in the two weeks preceeding the clinic visit. Due to the large number of swimming sites, the number of swimmers was too small at any particular site for analysis of the illness rates at each individual site.

D'Alessio et al. (1981) discussed several issues regarding their study design. They admitted that a unrepresentative sample of 27 controls had specimens taken for virus culture and that large numbers of undetected

infections in controls would make the findings conservative. The argument was similar for ill children without viral isolates. Imprecise or biased exposure determination was not a major problem, in the opinion of the investigators, and there was no reason to suspect systematic over- or under-reporting between ill and well groups. Swimming episodes were not defined by duration of the time spent in the water, by the extent of head submersion, and/or water ingestion. Person-to-person transmission of infection, in contrast to water transmission, was not felt to be so important since no swimming association was detected in children with clinically apparent viral illness from whom enterovirus was not isolated. Finally, the investigators concluded from the total fecal coliform and enterococcal counts, done at least weekly at each beach - for which they did not provide data - that there was no evidence of significant water contamination. However, occassionally high counts at an individual beach lead to closure of the beach for several days. The investigators indicated that if swimmers contaminated the unchlorinated water heavily enough to result in waterborne transmission, then this was not reflected in the actual bacterial monitoring. In summary, D'Alessio _et al_. revealed that they detected a significantly increased risk of enterovirus illness in children swimming at unpolluted Madison beaches which they felt was suggestive of waterborne transmission. Concurrent virological studies of swimmers and the swimming waters

utilized were deemed necessary for conclusive evidence.

The study undertaken by D'Alessio et al. (1981) is valuable and reasonably thorough. However, it is unfortunate that the bacteriological methodology and data were not available. More detail regarding the exclusion of cases and controls would also be a valuable contribution, as would data regarding the comparability of cases and controls. In addition, the measures taken to avoid recall bias (Sackett, 1979) should have been outlined in detail. More information about the statistical techniques utilized should also have been presented in the paper.

A very small prospective cohort study was undertaken by Philipp et al. (1985) on May 8, 1983, at a marine snorkel swimming event held at the Bristol City Docks in England. At the time of the registration for the event, each swimmer was interviewed and given a questionnaire. An additional copy of the questionnaire was given to the swimmer for completion by a person in a similar age group who preferably inhabited the same household, and was thus exposed to similar food and drink. Unfortunately, many of the young swimmers were reluctant to disclose both their age and information about other household members, such that the authors felt it necessary to admit that these factors could not be formally controlled. However, only two swimmers could not provide suitable controls. Food and drink were available from restaurants, mobile cafeterias, and waterside bars such that swimmers were asked to select their control from persons who did not attend the event. An

additional control group was selected from visitors to the city museum at dockside, an area immediately adjacent to the event. All visitors who appeared to be between 20 and 40 years-of-age (similar to the swimmers) were invited to take part in this control group and 75% of them participated. Subjects were asked to keep the questionnaire for seven days after the event before completing it and sending it back in a pre-paid addressed envelope. Swimmers who lived nearby comprised 59% (51 of 87 swimmers) of the event participants. These 51 swimmers were given a fecal specimen container with written instructions for diarrheal material collection, as well as a telephone number to arrange for specimen collection. Water samples for bacterial and viral analyses were collected from three swimming route locations during the event.

Of the 87 (11 female and 76 male) swimmers, 89% (77/87) completed questionnaires, versus 86% (75/87) of family-based controls and 93% (95/102) of dock visitor controls (Philipp et al., 1985). The time period reported on was deemed to be similar for swimmers and family-based controls since most questionnaires were returned together. Although swimmers were reluctant to reveal their ages, event organizers revealed that their ages ranged from 13 to 45 years-of-age, and that most competitors were between 20 and 35 years-of-age.

Gastrointestinal (GI) ailments were reported by 27.3% (21/77) of swimmers, 1.3% (1/75) of family controls, and 3.0% (3/95) of dock visitor controls (Philipp et al.,

1985). Statistically, there were a significantly larger number of GI symptoms in the swimmers than in either of the control groups (X^2=36.3, d.f.=2, p<0.001). There were no statistically significant differences between the number of persons with GI symptoms in the two control groups. Nongastrointestinal symptoms were reported by 6.5% (5/77) of swimmers, 2.7% (2/75) of family controls, and 6.3% (6/95) of dock visitor controls. The number of swimmers who reported these other symptoms was not significantly different from the numbers in either of the control groups. These symptoms included upper respiratory problems in four swimmers, two family and three dock visitor controls, syncope (fainting) in one swimmer, threadworms in one dock visitor control, dysmenorrhea in one dock visitor control, and a headache in one dock visitor control. No symptoms were noticed by 66.2% (51/77) of swimmers, 96% (72/75) of family controls, and 90.5% (86/95) of dock visitor controls.

The 27.3% (21/77 - three females and 18 males) of swimmers who experienced GI symptoms developed the symptoms within 48h after leaving the water, and 13% of these people stayed home, whereas another five consulted a Physician (Philipps et al., 1985). Three of the twenty-one swimmers experienced abdominal pain only, one had nausea, and 17 reported vomiting and/or diarrhea. Prior to the event, the swimmers were reported to be healthy.

No statistically significant differences existed between the number of swimmers and dock visitors who

purchased food or drank at the docks (Philipp _et al_., 1985), nor could food and drink consumption from home, or from both the docks and home (or the lack of it) account for GI illness in swimmers. The authors also concluded from their data that wetsuits did not protect against GI illness after each water exposure.

Bacterial analyses revealed that the total coliform densities per 100mL of water were: 24000, 91000, and 80000, at the start of the event, at the half way point of the event, and at the fifnish of the event, respectively (Philipp _et al_., 1985). The respective values for _E. coli_ were: 2000, 900, and 2500, and for fecal streptococci were: 14, 14, and 22. No bacterial or viral pathogens were isolated from the two fecal samples provided. No virus isolations were made from a five litre sample of the dock water collected on the day of the event.

Clinical data provided by the investigators for 17 of 21 swimmers with highly credible GI symptoms (i.e.: all cases of vomiting, instances of diarrhea accompanied by a fever or that were disabling, or cases of nausea or stomachache accompanied by a fever - as defined by Cabelli _et al_. (1982) did not support a viral aetiology. This was because a median GI illness incubation period of 36h, and a lack of accompanying headaches or myalgie were observed.

The investigators concluded that a causal association exists between prolonged swimming with the head immersed in Bristol City Docks water and GI illnesses (Philipp _et al_., 1985). In addition, snorkel swimming at the Bristol City

Docks were not encouraged, even when EEC guidelines (Comission of the European Communities, 1976) were met (based upon data acquired prior to the present study - where a similar event held on May 9, 1982, produced a GI symptom rate of 25% in 199 persons followed up, and the total coliform counts were within the EEC guidelines). The authors also requested a review of the EEC guidelines.

The study conducted by Philipp _et al_. (op cit) is intriguing, but it can be criticised on the following grounds:

1. The major flaw, as acknowlegded by the investigators, is the lack of information regarding potential confounding variables (eg. age, sex, socioeconomic status, etc.). As a result, the possibility of biased findings exists.
2. Additional information regarding the questionnaire utilized is warranted.

2.3 More complex studies

In the past few years, several large prospective cohort investigations of swimming-related illness have been initiated in the United States (Cabelli _et al_., 1979; Ktsanes _et al_., 1979; Cabelli, 1980; Cabelli, 1981; Cabelli _et al_., 1982; Dufour, 1982; Cabelli, 1983) and Canada (Seyfried _et al_., 1985a,b). Results derived from these studies were modelled in order to predict the level of swimming-related illness and to display the findings graphically (Cabelli, 1980; Cabelli _et al_., 1982; Dufour,

1982; Cabelli, 1983; Seyfried _et al_., 1985a,b).

Cabelli and his associates conducted a multi-year multiple-location prospective cohort research program of swimming-related illness in the United States and Egypt (Cabelli _et al_., 1979; Ktsanes _et al_., 1979; Cabelli, 1980; Cabelli, 1981; Cabelli _et al_., 1982; Dufour, 1982; Cabelli, 1983). A summary of the major American investigations may be found in a recent publication (Cabelli _et al_., 1982). The researchers wanted to establish whether illnesses were related to swimming in water polluted by sewage and to quantitatively relate such illness rates with marine recreational water quality. The studies were undertaken at: 1) New York City (a barely acceptable beach on Coney Island which was adjacent to an unsafe beach and a relatively unpolluted beach at the Rockways were compared) in 1973 to 1975, 2) Lake Pontchartrain, Louisiana (Levee Beach and Fountainbleau Beach) in 1977 to 1978, and 3) Boston, Massachussetts (Revere Beach and Nahant Beach) in 1978. The beaches were selected because they were frequented by many people who tended to swim on weekends only. Discrete trials were undertaken on Saturdays and Sundays only. Subjects were recruited at the beach, ideally from family groups. People who swam five days prior or subsequent to the weekend of interest, or at other locations on either weekend days were excluded. This ensured that exposure at a particular beach was limited to one or two days, decreased beach-to-beach and day-to-day variation in pollution, and permitted data analysis by trials (study days) or groups of

trials when mean indicator pollution densities were similar. Information on age, sex, ethnicity, and socioeconomic status (by a person-to-room ratio) was ascertained at the initial beach interview and during subsequent telephone follow-up. Information on bathing was acquired at the initial beach interview. Swimming was defined as complete exposure of the head to water and was ascertained by direct questioning and observation (whether or not the person's hair was wet). People who did not immerse their heads in the water were designated nonswimmers. Subjects' and observer information were compared at New York City in 1972. There was good agreement for immersion of the head in water, but not the period of immersion or time spent in the water with the head not necessarily immersed.

One or two days after the initial interview, participating families were sent a reminder letter which asked them to record any illnesses which occurred in the week susequent to beach activity (Cabelli et al., 1982). In the first and pretest year, a telephone number was provided so that follow-up medical or laboratory examinations could be done for people who became ill, but very few people called the number which was subsequently abandoned. Thereafter, eight to ten days after the initial beach interview, subjects were contacted by telephone to acquire demographic and symptomatic (gastrointestinal, respiratory - which included ear -, other, and disabling ailments) information. However, only gastrointestinal symptoms

(vomitting, diarrhea, nausea, or stomachache) were consistently both swimming and pollution related. Thus, only gastrointestinal (GI) symptoms were examined relative to bathing water indicator densities. As an alternative to follow-up medical and laboratory examinations, the credibility of the gastrointestinal information was confirmed by comparing the rates and trends of the total GI symptoms to highly credible GI symptoms (all cases of vomitting, instances of diarrhea that were accompanied by fever or that were disabling, or cases of nausea or stomachache accompanied by a fever.

Water samples were collected periodically on trial days at the time of maximum bather load which was generally between 11 a.m. and 5 p.m. (Cabelli _et al_., 1982). Usually, three to four samples were collected (at two or three sites from each beach) at chest depth about four inches below the water surface. The densities of: enterococci, _E. coli_, _Klebsiella_ sp., _Enterobacter_ sp., _Citrobacter_ sp., total coliforms, _Clostridium perfringens_, _P. aeruginosa_, fecal coliforms, _Aeromonas hydrophila_, and _Vibrio parahaemolyticus_ were determined at New York City. However, at Lake Pontchartrain, only the: enterococci, _E. coli_, _Klebsiella_ sp., _P. aeruginosa_, and fecal coliform densities were monitored. At Boston, only the enterococcal and _E. coli_ densities were determined.

The relationship of swimming-related (swimmer minus nonswimmer) GI symptom rates to the mean water indicator densities was evaluated by linear regression analysis. The

symptom rates for a particular weekend day (trial) and the associated mean indicator density was not generally analyzed as a point on a regression line because the number of nonswimmers was too small. Thus, it was decided to group the trials. Single-day trials were sorted according to increasaing indicator densities. Groups were defined by selecting natural breaks in the progression, such that trial days with similar indicator densities formed a group of data from which a geometric mean density and the associated rates for GI and highly credible GI symptoms could be determined. This grouping was performed for each indicator microbe. Attack rates for GI and highly credible GI symptoms were regressed against the mean indicator density. The log-linear regression equation of:

$$Y = a + (b*\log(X))$$

was utilized (where X was the mean indicator density and Y the GI symptom rate).

The percentage of follow-up responses during the three study years ranged from 77.2 to 86.6 per cent (Cabelli *et al.*, 1982).

Correlations between highly credible and total GI symptoms and all the mean indicator densities, at New York City beaches in 1973 to 1975, revealed that the enterococci were optimal indicies (r=0.96, and r=0.81, respectively). However, fecal coliforms (r=0.51, and r=0.36, respectively) and *E. coli* (r=0.58 and r=0.51, respectively) did not correlate well with swimming-related GI symptoms. Using their entire study data, regression lines and correlation

coefficients were provided for the enterococci and for E. coli versus both total and highly credible GI symptoms. The enterococcus regression lines had higher r values ($r=0.82$ for total GI symptoms, and $r=0.75$ for highly credible GI symptoms) than did E. coli ($r=0.25$, and $r=0.54$, respectively). The E. coli regression lines had shallower slopes and crossed the X axis at much lower densities than the enterococcus regression lines, but low densities for both indicators were associated with appreciable attack rates. For example, attack rates for highly credible GI symptoms of roughly one per cent were associated with enterococcus densities of about 10 per 100mL of water. A graph was provided of the regression relationship between total and highly credible GI symptoms versus the mean enterococcal densities (Figure 2.1). From this it was possible to predict the illness rates from the mean enterococcal densities. In addition, the relative importance of swimming in sewage-polluted water as a route of enteric illness transmission was evaluated by determining the ratio of swimmer to nonswimmer GI rates versus the mean enterococcal density. All cases acquired by routes other than swimming were assumed to be included in nonswimmer rates. Regression lines derived for the trials clustered by indicator densities are displayed in Figure 2.2. The rates for both total and highly credible GI symptoms were the same at a mean enterococcus density of approximately 1 per 100mL of water, but at 10 per 100mL of water, the rates for total and highly credible GI symptoms

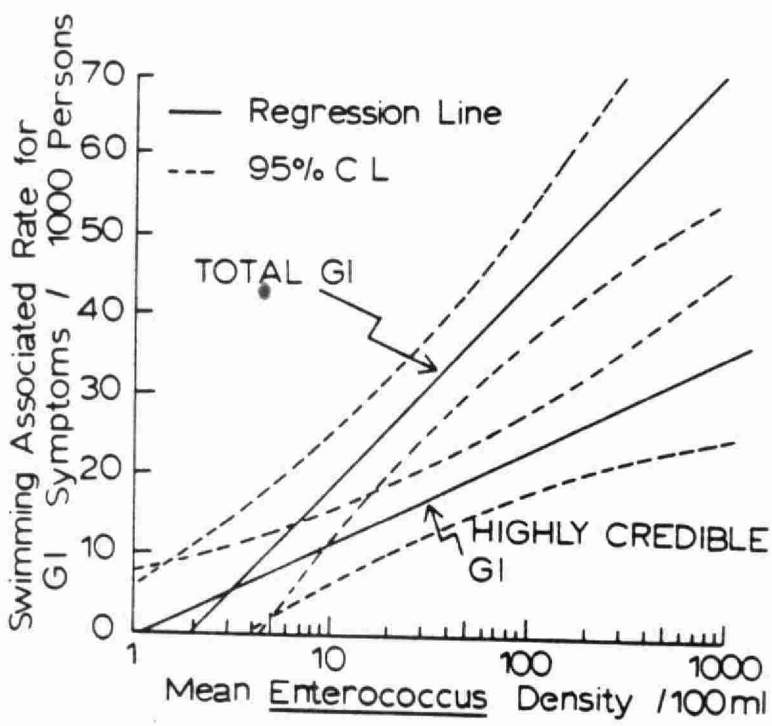

Figure 2.1 Regression of Swimming-Associated Gastrointestinal (GI) Symptom Rates on Mean Enterococcus sp. Densities in the Water (after Cabelli et al., 1982).

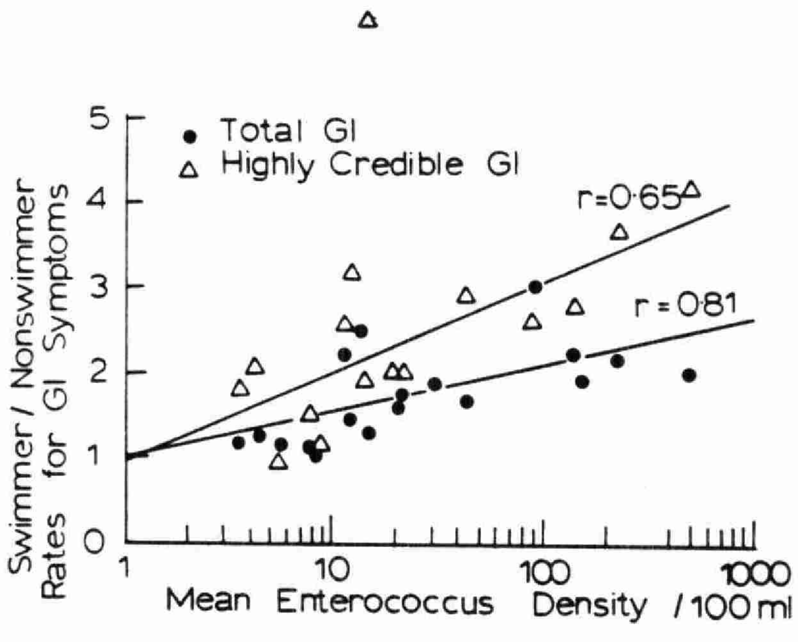

Figure 2.2 The Relative Risk of Swimming in Sewage-Polluted Waters as Shown by the Regression of the Ratio of Swimmers to Nonswimmers (Background) Rates for Gastrintestinal (GI) Symptoms on the Mean Enterococcus sp. Density in the Water (after Cabelli et al., 1982).

were 1.5 times for swimmers and twice those for nonswimmers respectively.

As a result of their investigations, Cabelli and his associates concluded that the risk of GI illness associated with swimming in marine waters contaminated with municipal wastewaters is related to the water quality, as reflected by the mean enterococcus density (Cabelli _et al._, 1982). In addition, the risk is measurable at very low levels of pollution. For example, GI rates of one per cent were associated with ingestion of one to five enterococci, based on swallowing 10 to 15mL of water which had an enterococcus density of approximately 10 per 100mL of water. Thus, it was suggested that swimming in sewage-polluted waters is not associated with insignificant risk of acquiring gastroenteritis. Furthermore, the results from these investigations favoured the enterococci and _E. coli_ as the optimal marine recreational water quality indicators of the potential risk of developing GI problems. Interestingly, the enterococci provided the clearest relationship.

Several criticisms can be directed towards the extensive studies undertaken by Cabelli _et al._ (1982). These fall in three main regions - methodology of epidemiological investigations, techniques employed for bacteriology, and methods of data analyses.

Let us first consider some problems hidden within the methodology of the investigation:

1. The effect of potential confounding variables was not taken into consideration. For example, pooling of data

from several different locations and time periods (R. Lacey, personal communication) could provide misleading results. Demographic information is frequently of critical importance to an understanding of how other variables such as age, sex, race, contact person, etc., can interact to produce misleading results.

2. The presentation of the results of epidemiological investigations must be rigorous. For example, Cabelli _et al_. (1982) failed to indicate whether a spokesperson reported the illness rates for a particular beach group (A. Dufour, personal communication, suggests that illness rates were reported by a spokesperson). Interestingly, the potential for bias exists if a contact person is utilized, and not taken into consideration in the anlysis. The reason for this lies in the fact that the contact person is more likely to report accurately the information about him or herself than other members of the group.

3. The definition of a swimmer is a critical parameter in the production of models relating illness to recreational water quality indicies. Cabelli _et al_. (1982) defined a swimmer as a person who completely exposed his or her head to the water (i.e. immersed their head in the water). The remaining individuals were classified as nonswimmers, regardless of whether they entered the water or not. Seyfried _et al_. (1985a,b) suggest that the reporting of head immersion by the contact person may not always be accurate for other members of the beach group. Furthermore, several different categories of

swimming-related illness can arise in the absence of the ingestion of water, however necessary that may be for the development of GI symptoms. Thus, it may be preferable to define nonswimmers as those who did not enter the water at all (e.g. Seyfried et al., 1985a,b) rather than to use the definition of Cabelli et al. which would result in abnormally high illness rates in the nonswimmers compared to a truely representative background population.

The methods of sampling and bacteriology utilized by Cabelli et al. (1982) also require further comment:

1. The collection of samples for the determination of bacterial contents must be systematic if the data is to be used in a rigorous fashion. For example, a constant number of samples from a given number of sample locations is optimal, rather than the "three or four samples collected at two or three sites".

2. The water samples should be collected in locations where they are going to be representative of the water coming into contact with the majority of the swimming population. Clearly the collection of water samples at chest depth about four inches below the water surface may not be optimal, as this water may rarely come into contact with a large proportion of the swimmers.

Finally, some comments on the modelling techniques of Cabelli et al. warrant some discussion:

1. The illness rate may be expressed in a number of different ways. Cabelli et al. (1982) utilized a method of subtracting nonswimmers (expressed as a proportion of the

total number of persons interviewed) from swimmers (expressed as a proportion of the total number of persons interviewed). Though Cabelli et al.'s justification of this ratio was unclear, it would appear to be a method of subtracting the background illness rate to compensate for the proportion of swimmers who became ill due to reasons other than those related directly to swimming activity. Presumably, Cabelli et al. (1982) believed that the background population and swimming population were equally susceptible to illnesses acquired from sources other than swimming. This method may be incorrect due to the use of an oversimplified background correction factor which may not behave so predicatbly as thought (e.g. due to various confounders such as age). According to Blum and Feachem (1983): "the diseases and infections considered in environmental impact studies are, without exception, unevenly distributed among various age groups". For example, the highest incidence for most types of diarrhea occur in young children. Further discussion of this problem is presented in subsequent chapters.

2. Cabelli et al. (1982) grouped trials with similar indicator densities, and regressed the geometric means of the bacterial counts in each of these groups against the illness rate in swimmers (corrected for background illness). This method is unsatisfactory because it failed to take into consideration the possible effects of confounders. Lacey (pers. comm.) has commented about this point in more depth. The technique of clustering the

average disease rates using the method of Cabelli et al. (1982) may not be accurate as there was a logarithmic transformation on the X-axis, which was not compensated for on the Y-axis, and for which there is no convincing justification (Cabelli, 1980). Interestingly, the assumption regarding the shape of the dose-response curve in the range of the data of Cabelli et al. was apparently unsupported, and it is unlikely that the complexity of the systems under analysis would be embraced in a universal two-variable model.

In more recent studies conducted by Cabelli (1983), he suggested a major role for Norwalk-like viruses and the human retrovirus in the production of waterborne outbreaks of acute gastroenteritis. Cabelli also postulated that there was a strong indication that the aetiological agent of the acute gastroenteritis detected in swimmers was of viral origin, probably due to the human rotavirus or one of the Norwalk-like viruses.

Cabelli (1983) suggested that highly credible GI illness in swimmers can be predicted based on his previous findings (Cabelli, 1980; Cabelli et al., 1982), and the enterococcal and E.coli densities from the equations:

$$Y = (12.25 * \log_{10}X) + 0.073 \qquad \text{... enterococci } (r=0.75)$$

$$Y = (6.32 * \log_{10}X) + 5.71 \qquad \text{... } E.\ coli (r=0.56).$$

Cabelli (1983) used this information along with beach usage data derived from photographic surveys and bacterial counts to investigate further the number of expected

ilnesses. The study was performed at several locations along the New York Bight during the summers of 1980 and 1981. While this study makes a valuable contribution to the eventual applications of recreational water quality data, it was based upon a rather imprecise and inacurrate method of epidemiological investigation. Interestingly, Cabelli proposed that the male-specific, single stranded RNA and DNA coliphages f-2 (MS-2) and f-1 (Fd) might represent the best alternative marine recreational water quality indicators of GI illness (should the enterococci require replacement). This would occur if their disinfection and transport survival characteristics did not approach those of the viral agents associated most frequently with waterborne disease (i.e.: hepatitis A, the Norwalk-like viruses, and the human rotavirus, although the role of hepatitis A seems to be of lesser importance in swimming-related illness than the latter two according to Cabelli).

Dr. A.P. Dufour, a colleague of Cabelli's, presented an intriguing paper on fresh water quality and swimming-related illness, at a symposium in Florida during 1982. Prospective cohort studies were undertaken at two freshwater bathing beaches. One beach was located at Keystone Lake, a man-made lake 15 miles from Tulsa, Oklahoma and the other was located on Lake Erie, at Erie, Pennsylvania. The freshwater trials utilized procedures similar to those in the marine investigations (Cabelli _et al._, 1974; Cabelli _et al._, 1979; and Cabelli, 1980).

However, the method of data analysis required modification because freshwater beach-goers tended to swim a great deal more than people at marine beaches, such that there were fewer control subjects. Because the nonswimmers at each beach were demographically alike (although no data were provided to support this statement), the nonswimmers from both beaches were combined into one control group. The follow-up telephone survey recorded information about various symptoms which might have occurred in the nine- to ten-day period between swimming and inquiry. Although multiple bacterial water quality indicators were examined, only E. coli, the enterococci, and fecal coliforms were considered.

Figures 2.3 to 2.6 display the results from the freshwater studies (Dufour, 1982). In Figure 2.3, the relationship of enterococcal density to highly credible GI illness is shown. The slope of the regression line from the marine data (Cabelli, 1980) was about twice that found from the freshwater data (11.6 versus 6.1), although the correlation coefficients were similar (0.71 versus 0.65). There was a much lower, and statistically significant ($p=0.05$ by the Wilcoxon rank sum test) average swimming-related illness rate detected in freshwater swimmers (6.2 per 1000 persons) relative to that found in marine water swimmers (14.8 per 1000 persons). Regression lines for highly credible GI illness on E. coli densities (Figure 2.4) show that the slope of the line from the marine data was greater than that for the freshwater data,

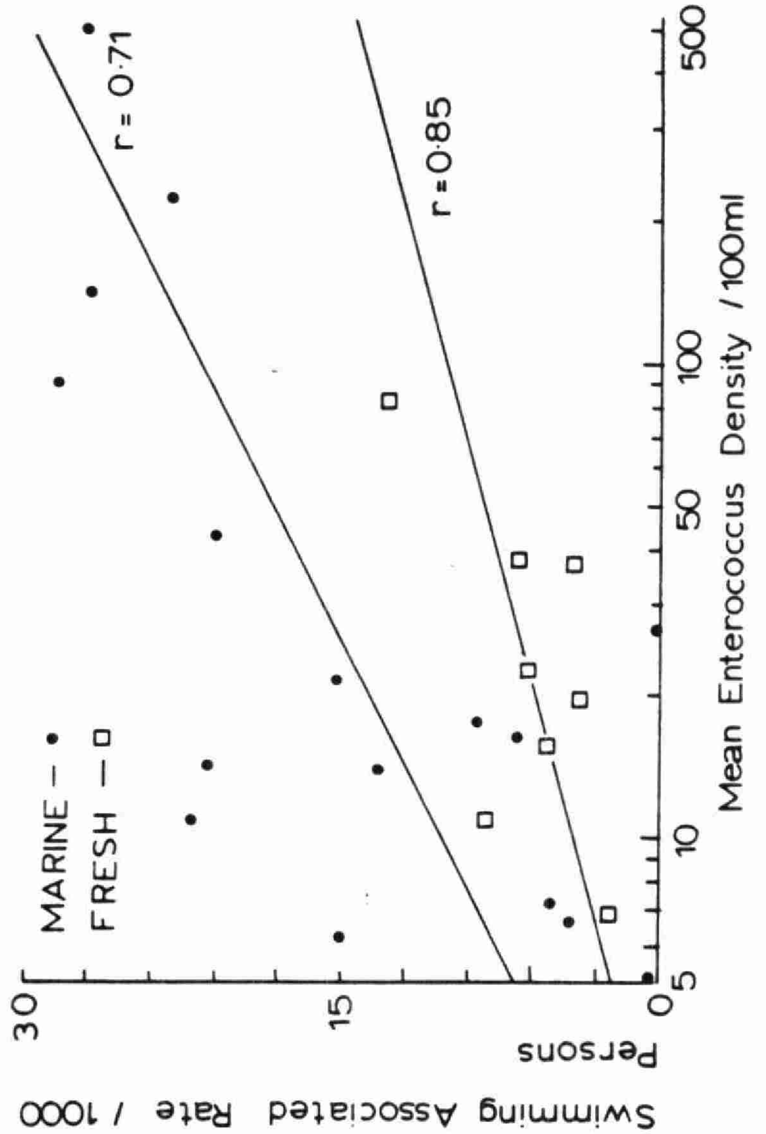

Figure 2.3 Comparison of Gastrointestinal (GI) Symptom Rates at Marine and Fresh Water Bathing Beaches using Mean Enterococcus sp. Density as the Index of Water Quality (After Dufour, 1982).

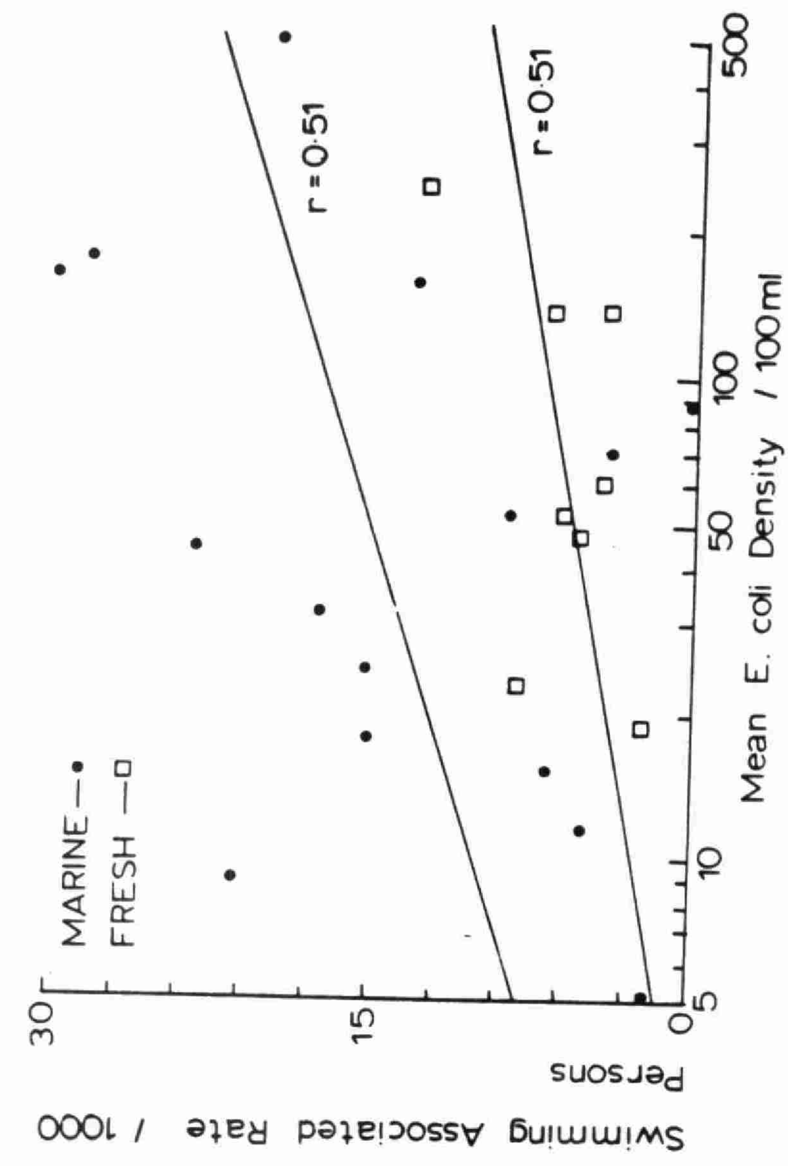

Figure 2.4 Comparison of Gastrointestinal (GI) Symptom Rates at Marine and Fresh Water Beaches using Mean E. coli Density as the Index of Water Quality (After Dufour, 1982).

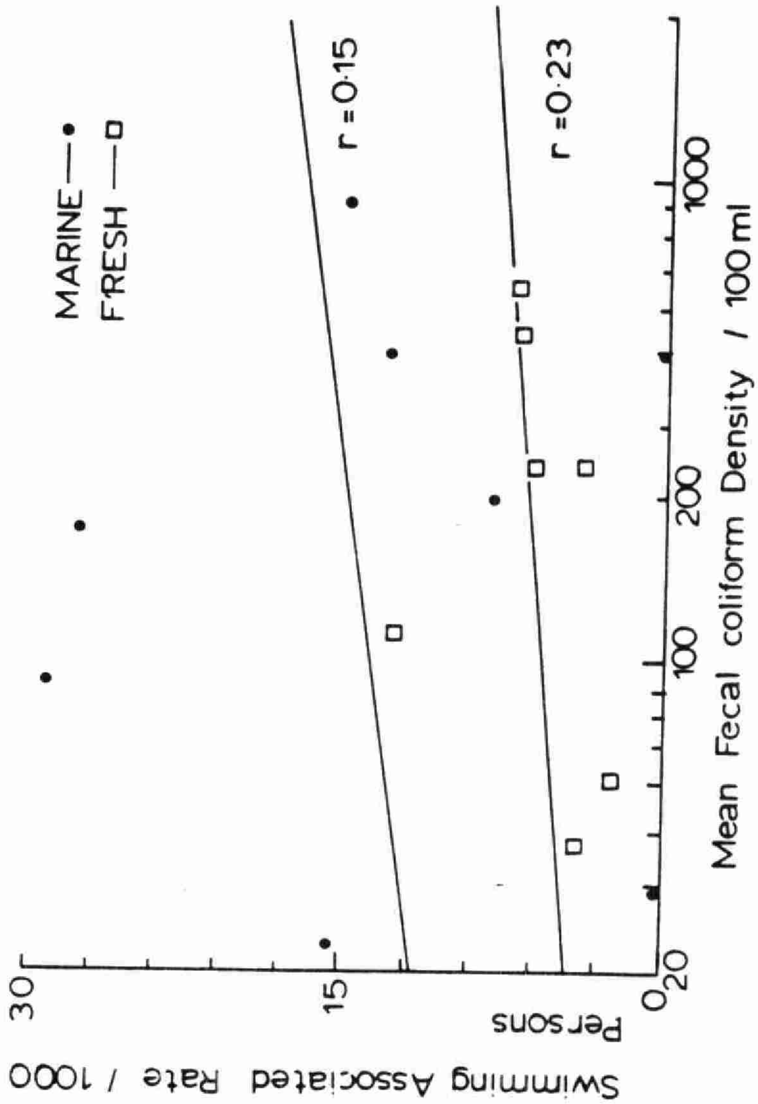

Figure 2.5 Comparison of Gastroinestinal (GI) Symptom Rates at Marine and Fresh Water Bathing Beaches using Mean Coliform Density as the Index of Water quality (After Dufour, 1982).

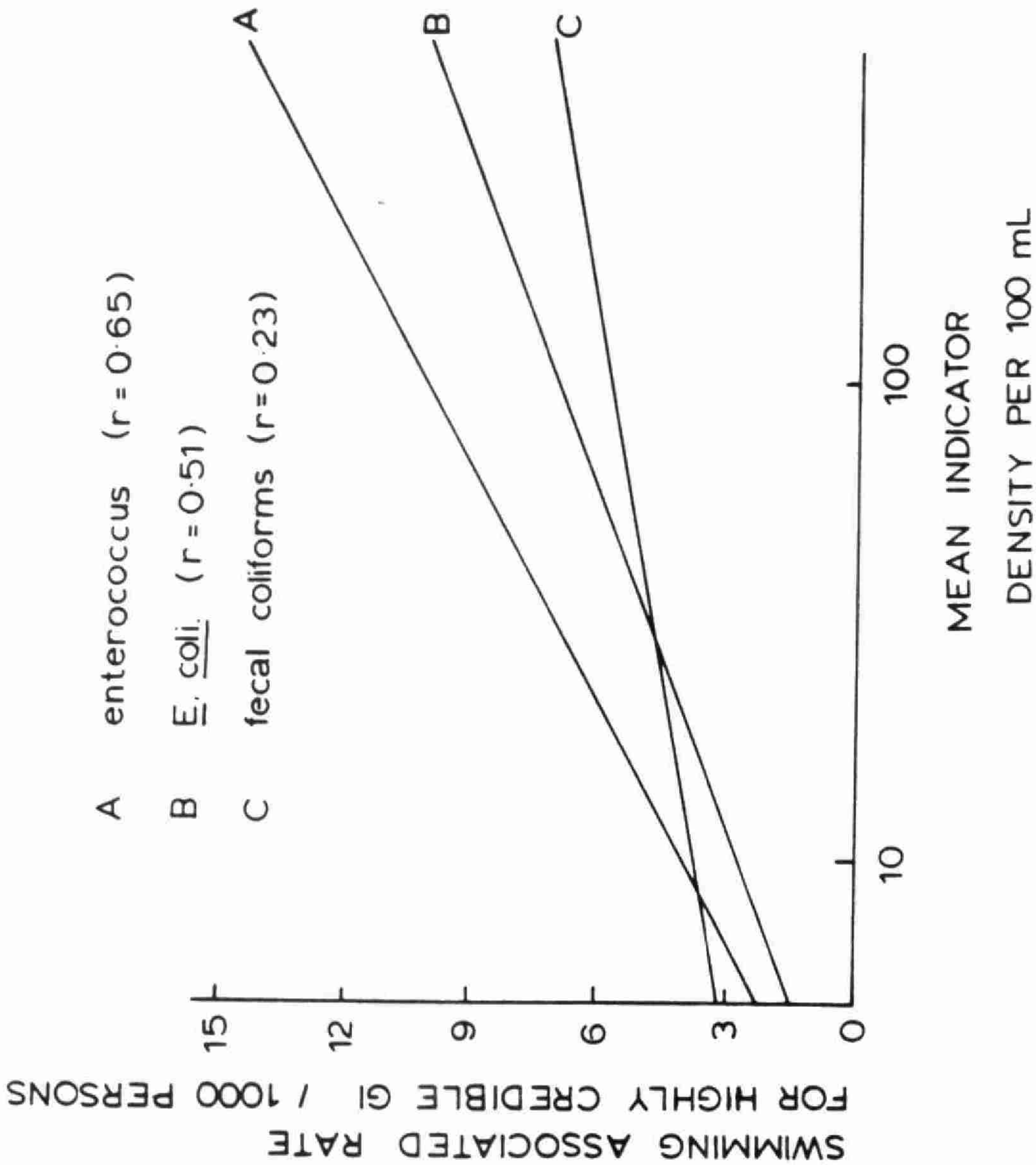

Figure 2.6 Relationship of Enterococcus sp., E. coli, and Fecal Coliform Mean Density with Gastrointestinal (GI) Symptom Rates of Fresh Water Bathing Beaches (After Dufour, 1982).

but not as markedly as that for the enterococci (7.3 versus 4.7). The correlation coefficients for the freshwater and marine data were quite similar (0.514 versus 0.513). Figure 2.5 displays the regression lines for highly credible GI illness on fecal coliform densities. Both the slopes for the marine (Cabelli et al, 1979) and freshwater data were quite flat (3.2 and 2.0, resperectively), and the correlation coefficients were small (marine=0.15, freshwater=0.23). The three freshwater health effects versus water quality indicator regression lines were compared in Figure 2.6. The order from highest to lowest correlation coefficients of the regression lines was enterococci (r=0.65), E. coli (r=0.51), and fecal coliforms (r=0.23).

Dufour (1982) also presented results from a small concurrent investigation of the relationship between waterborne microbe-bearing particulates and swimming-related health effects. The aim of the study was to ascertain if an association existed between particles larger than 3u and the incidence of GI symptoms in persons swimming on the day that measurements were made. The density of particles 3u or larger that were associated with E. coli colonies was determined, as well as the average number of E. coli per particle, and usual enumerations (Dufour et al., 1981). Each water sample was divided into two portions. One portion was tested as usual, and the other was filtered through a 3u pore size Nucleopore filter. The bacteria on the particles were desorbed and

dispersed by blending in a buffered surfactant solution. The *E. coli* in the desorbed bacterial suspension and the filtrate were quantified on the mTec medium after refiltering each through a 0.45u filter (Gelman, GN6). The number of particles associated with *E. coli* detected in the filtrate from the density found by the usual method. It was assumed that the *E. coli* in the filtrate were non-particle related cells. The number of *E. coli* per particle was determined by dividing the total number of *E. coli* desorbed from the particles by the total number of particles associated with *E. coli* colonies. The risk attributed to swimming (per cent of illness in swimmers due to swimming exposure, i.e: attributable risk) was for total GI symptoms because highly credible GI symptoms had frequencies of occurrence less than one on many trial days. The risk values were ranked in increasing order. The relatedness of the attributable risk to the *E. coli* density per 100mL of water, to the density of *E. coli* associated particles at least 3u in size, and the density of the *E. coli* particle was ascertained using Spearman's rank-difference correlation coefficient. The number of *E. coli* associated particles per 100mL of water had the highest degree of relatedness to the swimming-related risk. The *E. coli* density per 100mL of water also had a positive correlation with swimming-related risk but was roughly one-third of the magnitude detected with particle density. The correlation coefficient for attributable risk relative to *E. coli* density per particle indicated an inverse relationship

between the two variables.

From these freshwater studies, Dufour (1982) made the following conclusions:

1. As the quality of bathing water deteriorates, the risk of GI illness increases.

2. The enterococci correlated best with GI illness, just as in the marine studies.

3. There are definitely lower swimming-related GI illness rates for freshwater versus marine water swimmers, at equivalent indicator densities (probably due to dissimilar die-off patterns). This observation may be at variance with the expected bacterial survival patterns (Jones, 1984). This will preclude the use of a single criterion for marine and fresh recreational waters.

4. Both marine and freshwater swimmers exhibited similar symptoms.

5. The density of particles containing _E. coli_ seemed to be more closely related to the observed health effects than the density of _E. coli_ per 100mL, or the numbers of _E. coli_ per particle. This means that if there is a high probability of ingesting one particle, then that is more important than the average number of viable pathogens per particle. Dufour felt that might explain why significant swimming-related illness can occur in good quality water (i.e: ingestion of one paryicle containing multiple infectious units might explain the observation).

A draft of a recent paper written by Dufour (1985) provided some valuable additional information about the

marine and freshwater studies undertaken by Cabelli and his colleagues (1982; Dufour, 1982). Dufour (1985) revealed that:

1. The symptoms examined in the epidemiological surveys were grouped into: gastrointestinal, respiratory, eye, ear, and nose, and other ailments. Gastrointestinal (GI) symptoms included vomiting, diarrhea, stomachache, and nausea. Respiratory symptoms included sore throat, bad cough, and chest colds. Runny or stuffy nose, earache or runny ears, and red, itchy, or watery eyes were indicative of nose, ear, or eye problems, respectively. Other symptoms were defined as fever over $100^{o}F$, headache for more than a few hours, or backache.

2. The marine data were used to obtain the following predictive marine recreational water quality criteria, using the enterococci as the bacterial indicator:

$$y = 0.20 + 12.17 \log x,$$

where x was the geometric mean enterococcal density per 100 mL of water and y was the swimming-associated GI illness rate per 1000 swimmers (the latter was obtained by subtracting the nonswimmer GI illness rate of all individuals in grouped trial days from the swimmer GI illness rate, in the same grouped trial days). The data were reworked (Figure 2.7) in order to regress y on x, as is customary, instead of x on y, as done formerly; initially, the equation was:

$$\log x = 0.277y + 0.604$$

for the total GI symptoms, and

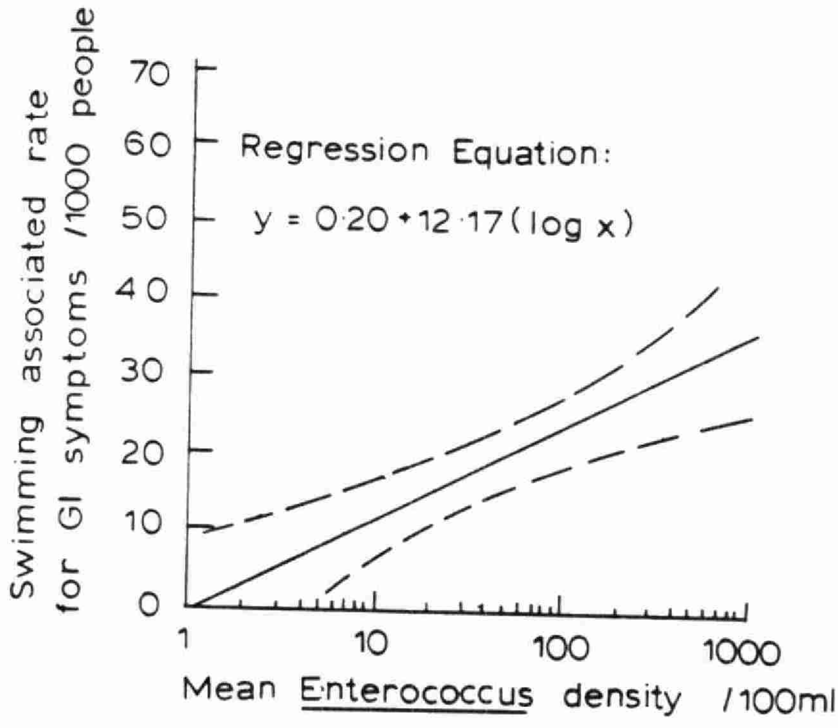

Figure 2.7 Relationship of Swimming-Associated Gastroenteritis to the Enterococci-Marine Data (From Dufour, 1985 in prep.).

$$\log x = 0.456y + 0.677$$

for highly credible GI symptoms; Cabelli, 1980.

3. Similar equations for fresh recreational waters were:

$$y = -6.28 + 9.40\log x,$$

where x was the enterococcal geometric mean indicator density per 100 mL of water, and y was the GI illness rate per 1000 persons (Figure 2.8), and

$$y = -11.74 + 9.40\log x,$$

for _E. coli_ (Figure 2.9). The freshwater studies were analyzed for each individual summer, and not by grouped trial days with similar indicator densities from a given swimming season (the technique used for the marine data). The analysis was done in this way because there was little variation in the bacterial indicators.

4. The equations used to calculate the upper 90 per cent confidence limits (Tables 2.1 to 2.3) for these three equations, respectively, were:

$$\log_{10}(\text{enterococcal geometric mean density}) + (1.65(\log_{10}\text{s.d.})/\text{sq.rt.}(n),$$

where n is the number of samples, and the $\log_{10}$s.d. was 0.7 for the enterococcal density in marine waters. For the enterococci in fresh water, the value of the $\log_{10}$s.d. was 0.4, and for _E. coli_ in freshwater, the value of $\log_{10}$s.d. was 0.4.

Dufour noted that an acceptable risk level of illness could be selected, and that this could be used to determine the bacterial guideline or standard. Consequently, if the

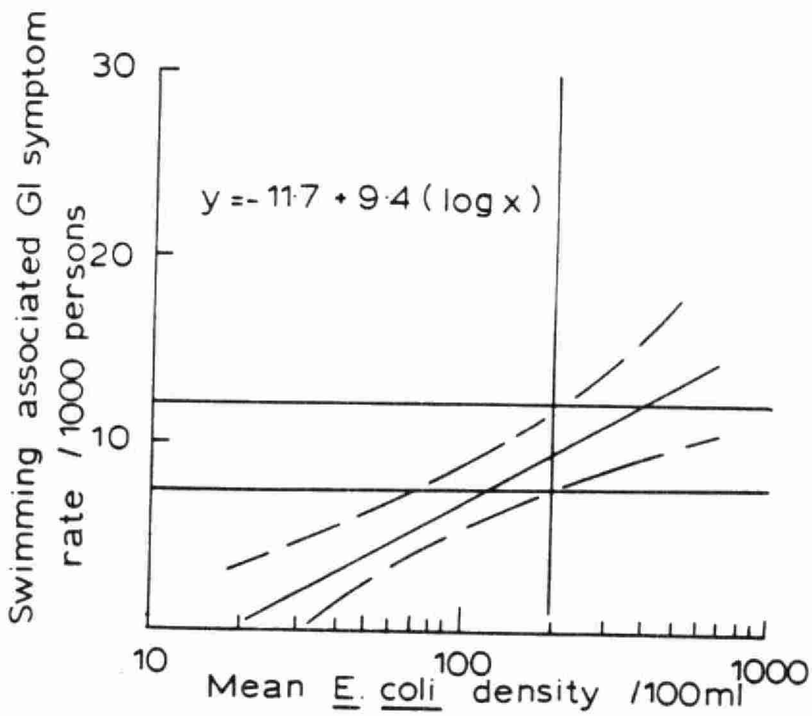

Figure 2.8 Relationship of Swimming-Associated Gastroenteritis to the Enterococci-Fresh Water Data (From Dufour, 1985 in prep.).

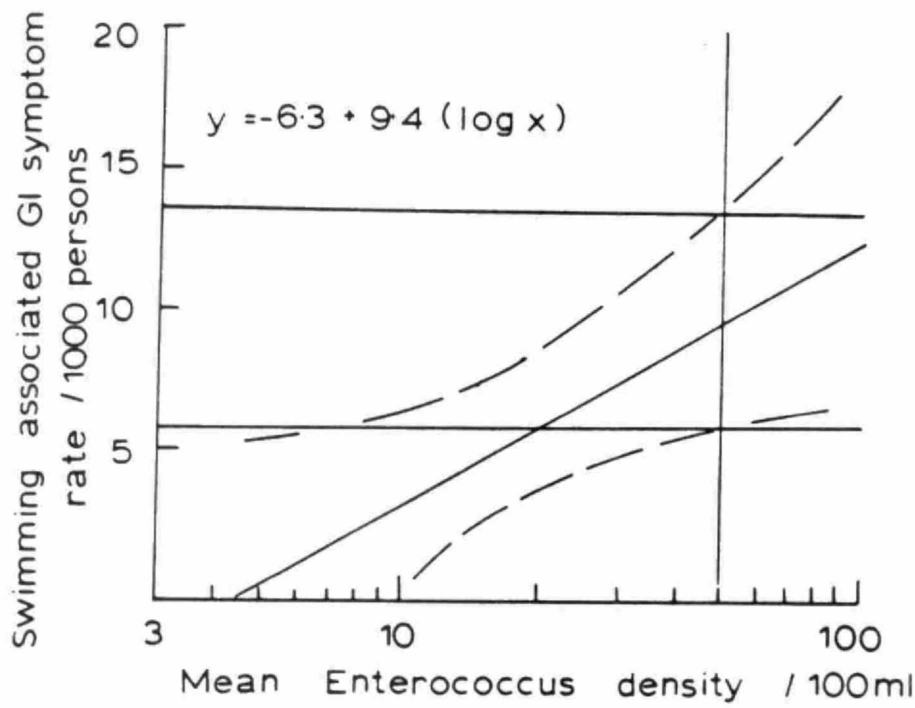

Figure 2.9 Relationship of Swimming-Associated Gastroenteritis to *E. coli* - Fresh Water Data (From Dufour, 1985 in prep.).

Table 2.1 Upper 90 Per cent Confidence Limit for Geometric Mean Enterococcus sp. Densities Based on the Number of marine Water Samples

Swimming-associated gastrointestinal rate per 1000	Geometric mean enterococci density per 100 mL.	Upper confidence limits for samples of size:				
		1	6	12	18	24
4	2[1]	29[2]	6[3]	4	4	3
5	2	29	6	4	4	3
6	3	43	9	6	6	5
7	4	57	12	9	7	7
8	4	57	12	9	7	7
9	5	71	15	11	9	9
10	6	86	18	13	11	10
11	8	114	24	17	15	14
12	9	129	27	19	17	15
13	11	157	33	24	21	19
14	14	200	42	30	26	24
15	16	229	47	34	30	28
16	20	286	59	43	37	34
17	24	343	71	52	45	41
18	29	414	86	62	54	50
19	35	500	104	75	66	60
20	42	600	124	91	79	72
21	51	729	151	110	95	88
22	62	886	184	134	116	107
23	75	1072	222	162	140	129
24	90	1286	267	194	168	155
25	109	1557	323	235	204	188
26	132	1886	391	284	247	227
27	159	2272	471	343	298	274
28	192	2743	569	414	359	330
29	233	3329	690	502	436	401
30	281	4015	832	606	526	484

Legend:

1 - Calculated to nearest whole number using the equation:

$\log_{10}$mean enterococcus density = (illness rate/1000 - 0.20)/12.17

2 - Upper 90% confidence limit on single sample = $\log_{10}$(enterococcus geometric mean density per 100 mL) + 1.65*($\log_{10}$s.d.),
where $\log_{10}$s.d.=0.7

3 - Upper 90% confidence limit = $\log_{10}$(enterococcus geometric mean density per 100 mL) + (1.65*$\log_{10}$s.d.)/sq.rt.(n),
where n is the number of samples, and the $\log_{10}$s.d.=0.7.

(from Dufour, 1985).

Table 2.2 Upper 90 Per cent Confidence Limit for Geometric Mean Enterococcus sp. Densities Based on the Number of Freshwater Samples

Swimming-associated gastrointestinal rate per 1000	Geometric mean enterococci density per 100 mL.	Upper confidence limits for samples of size:				
		1	6	12	18	24
1	6[1]	27[2]	11[3]	9	9	8
2	8	36	15	12	11	11
3	10	46	19	16	14	14
4	12	55	22	19	17	16
5	16	73	30	25	23	22
6	20	91	37	31	29	27
7	26	119	48	40	37	35
8	33	151	61	51	47	45
9	42	192	78	65	60	57
10	54	247	100	84	77	74
11	69	315	128	107	99	94
12	88	402	164	136	126	120

Legend:

1 - Calculated to nearest whole number using the equation:

$\log_{10}$mean enterococcus density = (illness rate/1000 + 6.28)/9.40

2 - Upper 90% confidence limit on single sample = $\log_{10}$(enterococcus geometric mean density per 100 mL) + 1.65*($\log_{10}$s.d.),
where $\log_{10}$s.d.=0.4

3 - Upper 90% confidence limit = $\log_{10}$(enterococcus geometric mean density per 100 mL) + (1.65*$\log_{10}$s.d.)/sq.rt.(n),
where n is the number of samples, and the $\log_{10}$s.d.=0.4.

(from Dufour, 1985).

Table 2.3 Upper 90 Per cent Confidence Limit for Geometric Mean *E. coli* Densities Based on the Number of Freshwater Samples

Swimming-associated gastrointestinal rate per 1000	Geometric mean *E. coli* density per 100 mL.	Upper confidence limits for samples of size:				
		1	6	12	18	24
1	23[1]	105[2]	43[3]	36	33	31
2	29	133	54	45	41	40
3	37	169	69	57	53	50
4	47	215	87	73	67	64
5	60	274	112	93	86	82
6	77	352	143	119	110	105
7	99	453	184	154	142	135
8	126	576	234	195	180	172
9	161	736	299	250	230	220
10	205	937	381	318	293	280
11	263	1202	489	408	376	359
12	335	1531	623	519	479	457

Legend:

1 - Calculated to nearest whole number using the equation:

$\log_{10}$mean enterococcus density = (illness rate/1000 + 11.74)/9.40

2 - Upper 90% confidence limit on single sample = $\log_{10}$(enterococcus geometric mean density per 100 mL) + 1.65*($\log_{10}$s.d.),
where $\log_{10}$s.d.=0.4

3 - Upper 90% confidence limit = $\log_{10}$(enterococcus geometric mean density per 100 mL) + (1.65*$\log_{10}$s.d.)/sq.rt.(n),
where n is the number of samples, and the $\log_{10}$s.d.=0.4.

(from Dufour, 1985).

geometric mean over a swimming season exceeded the upper 90 per cent confidence limits, then remedial action should ensue.

5. Dufour recommended that at least 12 water samples should be collected at equal time intervals throughout the swimming season. Sample collection near the centre of the beach, at a water depth of between waist and chest, was advocated. On beaches which have a long shoreline, collection of multiple samples at one sampling time was recommended (i.e.: one collected at either extreme, and one collected in the center). Seasonal compliance, Dufour noted, can be determined by calculating a geometric mean from the densities of single samples or the mean densities, if multiple samples were obtained at each site.

6. It was acknowledged that the above numerical criteria may be invalid if the population contributing the fecal wastes becomes small, or if epidemic conditions arise in a community. In such instances, the pathogen-indicator ratio becomes unpredictable.

During the summer of 1980, a prospective cohort investigation of swimming-related illness and recreational water quality was conducted by our laboratory (Seyfried _et al_., 1985a,b). Ten freshwater beaches in Southern Ontario, Canada were selected for study because they attracted large crowds and were considered representative of a wide range of recreational water quality (Seyfried _et al_., 1985a). Greater than 8000 people were interviewed on weekends. Family groups of size six or less, with the mother acting

as the contact person (spokesperson for follow-up), were considered ideal. At the beach, the following information was determined: the age, sex, previous or current illness record for the past four days, swimming record for the past four days, whether the person swam or would swim on the interview day, the duration of time spent in the water, whether the head was immersed, the best time of the day to telephone the contact person, and the contact person's address. Although three follow-up methods were employed, only telephone follow-up was included in the analysis due to the heavy selection bias in the other forms of follow-up. The three methods of follow-up were as follows: 1) an interviewer telephoned the contact person within seven to ten days of the initial interview, and if contact was not achieved then a form was mailed to the contact person, 2) the interviewer mailed a reply form to the contact person, shortly after interview, in some areas, and 3) the contact person was requested to mail in the form given to him or her at the time of initial interview, in some locations. During follow-up, the date when symptoms were first noticed for: respiratory, GI, eye, ear, skin, and other ailments were ascertained, as well as the presence of sunburn. The follow-up information was used to determine: whether illness occurred within three days subsequent to swimming at a specified location, the symptoms of the illness, whether medical attention was sought, the physician's diagnosis, whether the disability resulted in staying at home, as well as confirmation of the

water exposure data. People who swam in alternate, or the same locations within four days prior to, or three days subsequent to a trial, were analyzed by including a separate variable (i.e.: swimming before or after) in the analysis.

Water and sediment samples were collected at each beach up to three times per day, and most beaches were sampled at least twice daily (Seyfried et al., 1985b). Both water and sediment were analyzed for fecal coliforms, fecal streptococci, coagulase-positive and coagulase-negative staphylococci, P. aeruginosa, and heterotrophic bacteria.

Seyfried et al. (1985b) used logistic regression models employing GENSTAT (a GENeral STATistical package; Alvey et al., 1977). The log odds of getting ill were regressed against the log of the bacterial count (a continuous variable) combined with discrete variables (e.g. age group, contact person, swimming before and after, etc.). After the final model was developed (in which the sample population was divided into groups by the discrete factors), each group was analyzed separately to ascertain if changes in the bacterial pollution level produced rougly equal changes in the illness rate for all the groups (i.e.: whether the graph of $\log_{10}(p/1-p)$ versus the bacterial pollution level had approximately equal slopes for all the graphs). If the final model included several significant discrete factors, as well as bacterial pollution, then a single graph was determined by calculating the expected number of people ill according to the model at any

arbitrary pollution level in each group defined by the discrete factors, adding the expected numbers to find the total expected number of people ill at this level of pollution, and solving for the intercept:

$$\log_{10}(p/1-p) = \log (E/P)/(1-E/P) = \text{intercept} + \log_{10}(\text{organism count}),$$

where E = Expected number of people ill, and

P = Total population size.

Although 6166 follow-up interviews were completed out of 8402, only telephone data were reported (Seyfried *et al.*, 1985a). Data from 4537 telephone interviews (2743 swimmers and 1794 nonswimmers) were examined. The crude symptom rates were presented in Table 2.4. Swimmers displayed substantially higher morbidity rates versus nonswimmers. Adjustments of the aggregated symptom data for sex, contact person, age, and swam before or after were small. Two age categories (under 20 and 20 years-of-age or older) were selected because of approximately balanced numbers of persons in each group and due to a higher incidence of otitis externa previously observed in swimmers under 19 years-of-age (Seyfried and Cook, 1984). Morbidity rates in swimmers were higher than in nonswimmers in most age categories (Table 2.5).

The overall study geometric means of the bacterial

Table 2.4 Crude Symptom Rates (*) Reported among the Swimmers and Nonswimmers who were followed up by Telephone

Type of illness	SYMPTOM RATES PER 1000 PERSONS: SWIMMERS: All Swimmers (N=2743)	Head Out (N=813)	Head Under (N=1930)	Nonswimmers (N=1794)
All illnesses	69.6	76.3	66.8	29.5
Respiratory	28.4	36.9	24.9	11.7
Gastrointestinal	15.3	17.2	14.5	3.9
Eye	9.8	6.2	11.4	6.1
Ear	6.9	1.2	9.3	2.2
Skin	6.9	4.9	7.8	2.2
Allergies	6.9	8.6	6.2	2.8
Other	10.2	13.5	8.8	5.6

* - An individual with multiple symptoms may be counted in more than one category.

(from Seyfried et al., 1985a)

Table 2.5 Morbidity Rates among Swimmers and Nonswimmers of Different Ages

	SWIMMERS (N=2743)			NONSWIMMERS (N=1794)		
Age (years)	Number ill	N	%	Number ill	N	%
0-5	46	377	12.2	15	246	6.1
6-10	36	413	8.7	0	270	0
11-15	22	329	6.7	3	216	1.4
16-20	30	266	11.3	5	174	2.9
21-40*	53	1123	4.7	24	735	3.3
41-70	4	235	1.7	6	153	3.9
TOTAL	191			53		

* - An estimated age was recorded when the respondent was not willing to divulge age information.

(from Seyfried _et al_., 1985a)

Table 2.6. Geometric Means of bacterial Counts for All Sampling Days

Organism	Geometric Mean	No. of Samples
Fecal coliform (water)	76	122
Fecal coliform (sediment)	816	111
Fecal streptococci (water)	43	124
Fecal streptococci (sediment)	456	109
Heterotrophic bacteria (water)	$4*10^4$	114
Heterotrophic bacteria (sediment)	$7*10^5$	111
P. aeruginosa (water)	3	125
P. aeruginosa (sediment)	62	52
Total staphylococci (water)	151	123

(after Seyfried *et al.*, 1985b).

Table 2.7. The Relationship between Types of illnesses among Swimmers and Bacterial Indicators(*)

INDICATOR ORGANISM	TYPES OF ILLNESS (**)	p Value (***) for Organism
Fecal streptococci (water)	Total illness	0.016
P. aeruginosa (sediment)	Total illness	0.36
Total staphylococci (water)	Skin	0.044
Total staphylococci (water)	Eye (head under)	0.002
Total staphylococci (water)	Total illness	<0.001
Fecal streptoccocci (water)	Gastrointestinal	0.069
Fecal coliforms (water)	Total illness	<0.001

Legend:

* Derived from the deterministic model.

** All swimmers unless otherwise noted.

*** Adjusted for confounders which were important for the specific model.

(after Seyfried *et al.*, 1985).

counts were listed in Table 2.6 (Seyfried et al., 1985b). Table 2.7 revealed the relationships between the bacterial indicators and types of illnesses derived from logistic regression modelling (which included the important confounders). Statistically significant relationships were detected, at the five per cent level or better, between total illness and the surface water isolates of total staphylococci, fecal coliforms, and fecal streptococci. Total staphylococci isolated from surface water also related with eye and skin illnesses. Figures 2.10, 2.11, and 2.12 display these relatiosnships, with each point on the graph illustrating a day when 50 or more swimmers were incorporated into the analysis. The deterministic models for the total staphylococcal and fecal coliform counts versus the total illness had correlation coefficients of 0.439 and 0.284, repectively. However, the value of fecal streptococcal counts versus total illness was 0.166.

Seyfried et al. (1985a,b) made the following conclusions from their study:

1) The best time to conduct surveys such as the one described was between 1:00 and 2:30pm on weekends, when the air temperature was 25°C or greater.

2) The geometric mean for the fecal coliforms from the beach waters did not surpass the Ontario guideline of 100 per 100mL of water. However, bacterial levels were at least ten times greater in the sediment versus the surface water. Clearly, the sediment may contribute to contamination of surface waters, particularly by wave action or bather

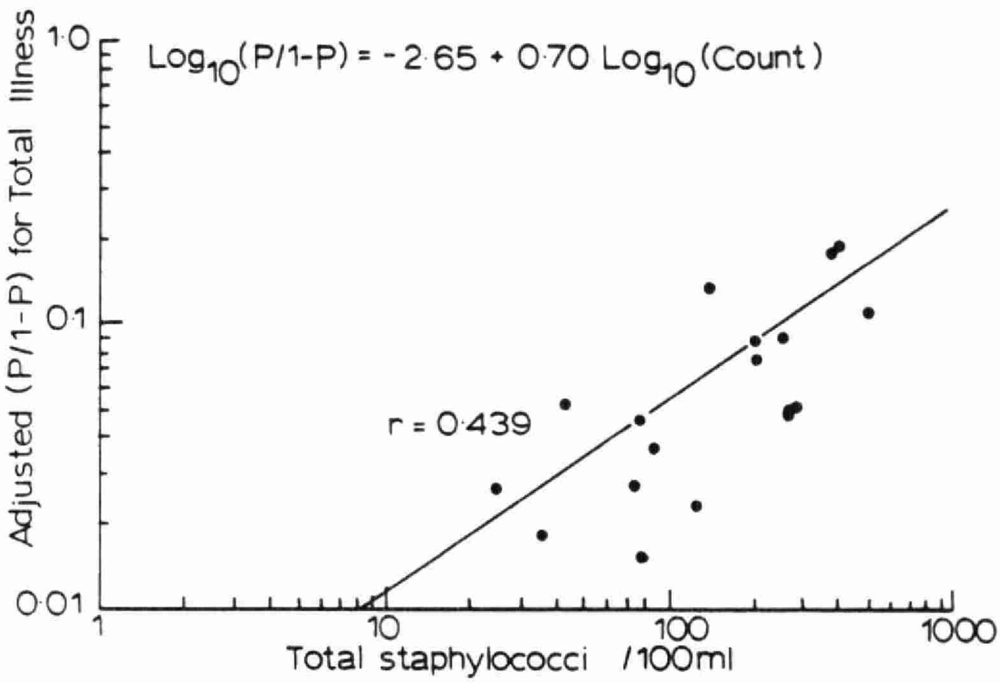

Figure 2.10 The Adjusted Odds of Swimmers Becoming Ill (p/1-p) Plotted against Total Staphylococci (After Seyfried *et al.*, 1985b).

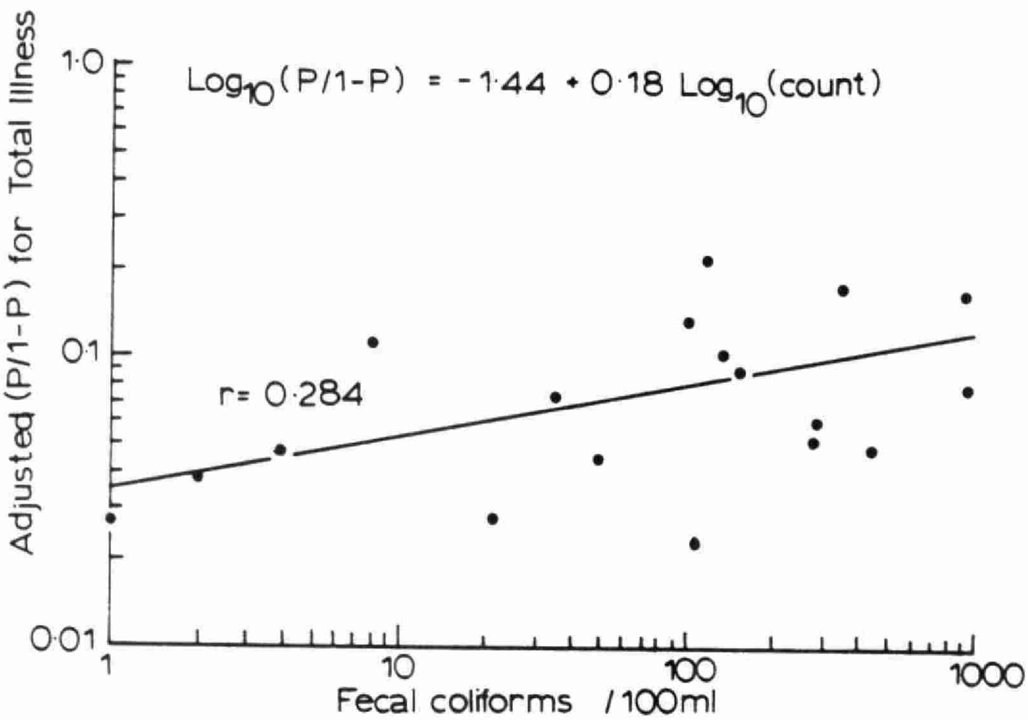

Figure 2.11 The Adjusted Odds of Swimmers Becoming Ill (p/1-p) Plotted against the Fecal Coliform Count (After Seyfried *et al.*, 1985b).

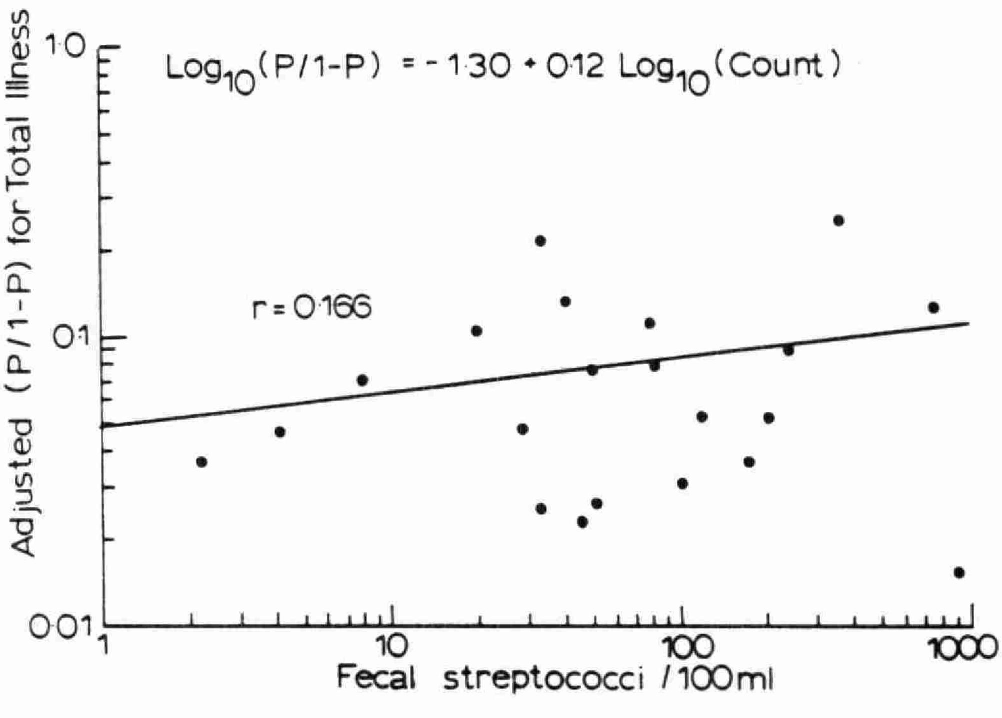

Figure 2.12 The Adjusted Odds of Swimmers Becoming Ill (p/1-p) Plotted against the Fecal Streptococcal Count (After Seyfried <u>et al</u>., 1985).

activity (unpublished data).

3) Total staphylococci, fecal coliforms, and fecal streptococci correlated best with swimming-related morbidity. Total staphylococci derived from surface water were correlated with total illness, eye, and skin illness. Fecal coliforms and fecal streptococci were also correlated, but to a lesser degree, with total illness.

4) The applicability of total staphylococci, along with fecal coliforms or E. coli, as indicators of the risk of swimming-related disease merits further investigation.

The studies of Seyfried et al. (1985a,b) were a clear improvement compared to those of Cabelli et al. (1982), however, this study has benefited from understanding several changes that could be made:

1) The number of bacterial samples collected at each location on each day could be constant.

2) The methods of follow-up could be rationalized. It was unfortunate that a large part of the data collected by Seyfried et al. (1985) could not be utilized because only telephone interviews were reported.

3) The illness categories were not defined in terms of specific symptoms in each category at the publication time. It was not mentioned that sunburn was not included, because it is often unrelated to bacterial count and elevates the illness rate.

4) The use of a limited number of age categories was not clearly justified.

5) Information, which in retrospect, could have been

included within the publication of Seyfried *et al.* (1985a,b) includes the fact that daily bacterial geometric means were used. Futhermore, no reasoning was presented for only using the data for 50 or more swimmers at any one location on any one day - the value of this assumption must be severly questioned, as it could introduce bias due to the exclusion of data acquired when bather activity was more limited (and must be considered unnecessary if the regression could be weighted in favour of the number of observations contributing to each data point).

2.1.3 Concluding remarks

Investigations of swimming-related illness in relation to recreational water quality have evolved from very simple to quite complex forms of study. Bearing in mind the caveats of the studies presented in this chapter, it is apparent that improvement in the design and analysis of the data are high on the list of priorities.

Further studies which incorporate modelling procedures could prove of great value to governments. In addition, it remains to be seen whether virological analyses concurrent with the bacteriological analyses will prove useful in such investigations.

CHAPTER 3

MICROBIOLOGICAL METHODS AND DATA ANALYSIS

3.1 Beach sites

The beaches selected for study during the summer of 1983 were located at: Albion Hills, Boyd, and Claireville Conservation Areas, on the Humber River, Heart Lake Conservation Area, Kelso Conservation Area, on the Sixteen Mile Creek, and at Professor's Lake, Brampton (Figure 3.1). A detailed description and map of each beach is provided in the Appendix (Section 9.1, Figures 9.1 to 9.6).

The six beaches selected for study were considered to be representative of a wide range of recreational water quality and attracted large numbers of visitors (Seyfried *et al.*, 1985).

3.2 Water sampling procedures

Surface water samples were collected at an approximate depth of 50 cm in sterile bottles (an air space of one inch was left at the top of the uniform sized sample bottles). Areas with maximum swimmer density were chosen for sampling. Unless the beaches were closed for swimming, due to excessively high bacterial counts, water samples were collected twice daily on weekends (generally between 10.00 am and 12.00 pm and between 1.00 pm and 2.30 pm - maximum bather activity usually occurred in the latter period).

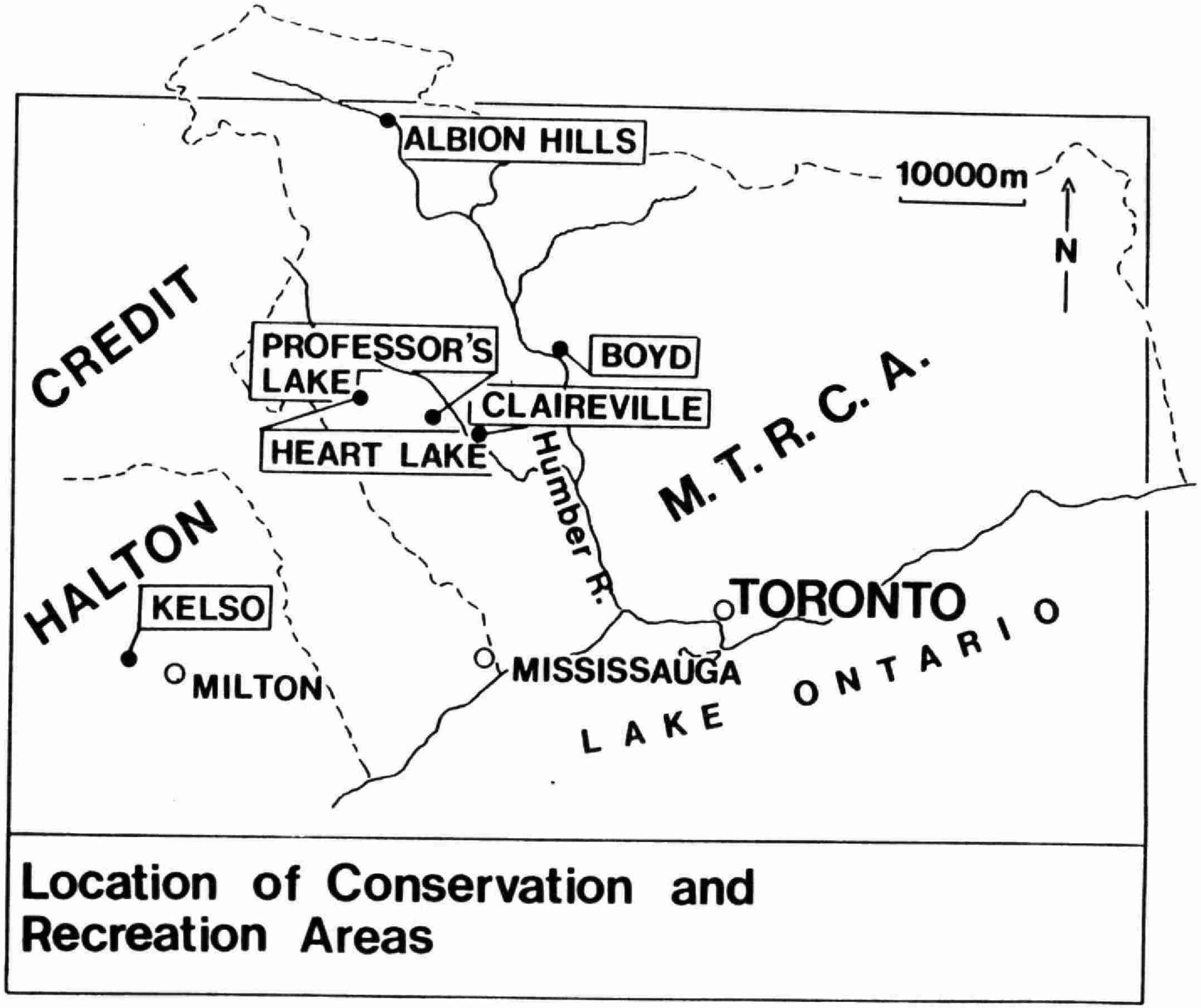

Figure 3.1 Location of Conservation and Recreation Areas Studied in 1983

Table 3.1 Record of the Sampling and Closure Dates for the Six Beaches Surveyed in 1983.

DATE SAMPLED	BOYD	CLAIREVILLE	ALBION	HEART LAKE	KELSO	PROFESSOR'S LAKE
June 25	0	0	0	0		
June 26	0	0	0	0		
July 1	0	0	0	0		
July 2	0	0	0	0		
July 3	0	0	0	0		
July 9	C	0	0	0		
July 10	C	0	0	0		
July 16	C	0	0	0		
July 17	C	0	0	0		
July 23	C	C	0	0		
July 24	C	C	0	0		
July 30	C	C	0	0	0	
July 31	C	C	0	C	0	
Aug 1	C	C	0	C	0	
Aug 6	C	C	0	C	C	0
Aug 7	C	C	0	C	C	0
Aug 13	C	C	0	C		0
Aug 14	C	C	0	C		0
Aug 20	C	C	0	C		0
Aug 21	C	C	0	C		0
Aug 27	C	C	0	C		0
Aug 28	C	C	0	C		0

Legend: 0 = OPEN; C = CLOSED; blank - not investigated.

Closed beaches were sampled once daily. A record of the sampling dates and beach status (open or closed) is listed in Table 3.1. The Boyd dam was dismantled early during July in the bathing season for public health reasons, and the remainder of the samples were taken within the Humber River. The sample sites at Kelso Conservation Area and Professor's Lake were added as study sites about half way through the study, in order to supplement epidemiological data, depleted by beach closures.

At the time of sampling, air and water temperatures were recorded, as well as a brief weather description. The visual turbidity of the water and whether the water was wavy or calm were recorded.

Counts were estimated of the number of persons on the beach who were not swimming, at the time of water sampling. In addition, estimations were also made of the number of persons in the water with their heads immersed and with their heads out of the water.

Collected water samples were chilled on ice during transport to the laboratory and were processed within six hours of arrival. The samples were analyzed, by standard methods at appropriate dilutions, for: total staphylococci, heterotrophic bacteria, fecal coliforms, E. coli, fecal streptococci, enterococci, P. aeruginosa. Campylobacter jejuni, and Legionella sp. (American Public Health Association, 1981, with variations listed below).

3.3 Bacteriological analyses

3.3.1 Total staphylococci

For the enumeration of total staphylococci, surface water samples were filtered through 0.45 um Gelman filters and incubated for 24 to 48 h at $35^{o}C$ on Vogel-Johnson agar (Difco) supplemented with 0.5 per cent sodium pyruvate (R. Alico, personal communiaction).

3.3.2 Heterotrophic bacteria

Aerobic heterotrophic bacteria were isolated on Casein-Peptone-Starch agar plates (Staples and Fry, 1973) which were incubated at $20^{o}C$ for seven days.

3.3.3 Fecal coliforms and E. coli

Fecal coliforms and E. coli were enumerated by filtering appropriate volumes of each sample and placing the filter on mTEC (medium for thermotolerant E. coli) media (Dufour et al., 1981). The plates were placed in plastic cakettes, with two ice jars in each, and incubated at $44.5^{o}C$ (Pagel and Vlassoff, 1979). Fecal coliform counts were made after 20+/-2h (Dufour et al., 1981). The filters were then transferred to pads, saturated with urea, for a 15 minute period. Yellow colonies were verified to be E. coli by oxidase and urease activities (Dufour and Cabelli, 1975), and growth on citrate agar (Difco) (Dufour et al.,

1981).

3.3.4 Fecal streptococci and the enterococci

A technique employing m-Enterococcus (mE) agar (Difco) was utilized to quantify fecal streptococci (American Public Health Association, 1971). The enterococci were also isolated by membrane filtration (Levin *et al.*, 1975). Filters were placed onto mE plates and incubated for 48h at 41°C (Levin *et al.*, 1975). Following incubation, the membrane was transferred to an esculin-iron agar plate. After 20 to 30 minutes at 41°C, small black spots were discerned under positive colonies (Levin *et al.*, 1975). To verify the colonies, the bile-esculin medium of Schwan was used along with: 1) growth at 45°C in BHI (Brain Heart Infusion) broth, 2) a negative catalase test, 3) growth on 40 per cent bile-blood agar, 4) a positive Gram stain, 5) acid reaction in litmus milk, and 6) esculin hydrolysis (Levin *et al.*, 1975).

3.3.5 *P. aeruginosa*

Pseudomonas aeruginosa were isolated by membrane filtration using two different media for comparative purposes. The filters were placed onto plates composed of an mPA media (modified media based on a procedure supplied by the Ministry of the Environment - see Appendix, Section 9.2) and mTIN medium, a new medium developed by our

laboratory (manuscript in preparation). The plates were incubated at 41.5°C for a minimum of 48h.

3.3.6 Campylobacter jejuni

For isolation of Campylobacter jejuni, water was filtered and the filters were added to BNP broth (modified Brucella broth, Appendix, Section 9.3) for enrichment. Flasks of broth containing the filters were incubated under microaerophilic conditions (i.e. air was evacuated from the anaerobic jar and replaced with a mixture of N_2, O_2, and CO_2) at 42°C for 48h, under the same atmospheric conditions as those described above.

3.3.7 Legionella pneumophila

The procedure employed for the isolation and enumeration of Legionella pneumophila (Appendix, Section 9.4) from water was developed by the Canada Centre for Inland waters in Burlington, Ontario (ASTM - American Society for Testing and Materials Task Group, D19:24:01:19 January, 1982).

3.4 Calculation of bacterial geometric means

As mentioned previously (section 1.64), the arithmetic mean of the logarithmically transformed bacterial data represents the best measure of central tendency, and bears

a direct relationship to the geometric mean of the original data (McNeill, 1985; Bordner, 1978). However, many Canadian and American water quality investigators refer to the result of this calcualation as the geometric mean of the data (L. Vlassoff, personnal communication; Bordner, 1978), and barring rounding errors, the values should be the same. Thus, in this thesis, the term geometric mean will be used in this context.

Geometric means of the bacterial counts were computed using the relationship:

$$\text{Geometric mean} = (x1 * x2 * \ldots * xn)^{1/n}$$

therefore,

$$\text{Geometric mean} = \exp\left((\ln(x1)+\ln(x2)+ \ldots +\ln(xn))/n\right),$$

where there are n observations.

Geometric means were calculated using all available data for:

1. The entire study period.
2. Each month of sampling.
3. Each beach which was sampled.
4. Open and closed beaches.
5. For each beach, taking into consideration whether it was open or closed.

Open beaches were sampled twice daily, and both of these values were included in the geometric mean

calculation (rather than using the arithmetic mean of the two values); in contrast, closed beaches were only sampled once daily. Thus, in some cases (e.g. over the period of study at open versus closed beaches), more weight was placed upon open beaches because of the more frequent sampling. Increased sampling frequency is likely to produce greater accuracy and precision, rather than introduce an additional variable which would make the results noncomparable.

For epidemiological purposes, bacterial geometric means were calculated daily by beach, month, and date, collectively, since the associated epidemiological illness odds were ascertained daily.

3.5 Statistical evaluation of bacterial geometric means

In order to test whether the bacterial counts for a specific organism were significantly different between open and closed beaches (i.e. by status), between beaches (i.e. by beach), between open and closed beaches (i.e. by beach and status), and between months (i.e.by month), the ANOVA (ANalysis Of VAriance) procedure in SAS (SAS, 1982a) was used. Multiple comparisons were made using the LSD test (Fisher's Least Significant Difference). As this procedure can only deal with the raw data, and provides no option to use the geometric means (arithmetic means of the logarithmically transformed data), it was decided to use the natural logarithms of the raw bacterial counts as the

data base for ANOVA. This provides a close approximation to the direct test of the geometric means. The LSD test is a significant difference test of the arithmetic means (SAS, 1982a).

3.6 Professor's Lake pilot study of bacteriaological sampling proceedures and evaluation of data quality

In order to evaluate the sampling procedures employed in this study, and the precision and accuracy of the data collected, a more detailed study of the variation in bacterial counts at a single site, and the amount of difference between multiple samples taken from Professor's Lake were investigated.

It would appear that a debate is presently escalating regarding the necessity to standardize bacteriological sampling procedures for recreational water quality in terms of existing guidelines. There has been no general consensus regarding the number, location, time, and depth of water at which samples are collected. Generally speaking, references to sampling procedures are vague (e.g. the American National Technical Advisory Committee, 1968). The Ministry of Health and Welfare Canada (1983) specify the collection of not less than five samples over not more than a thirty-day period. In contrast, the Ontario Ministry of the Environment specifies the collection of at least ten samples over a thirty day period).

In the prospective cohort epidemiological surveys of

swimming-related illness conducted to date by our laboratory (Seyfried *et al.*, 1985), it has been customary to collect a single recreational surface water sample for bacterial analysis at a water depth of approximately 50 cm, in an area with a maximum density of swimmers, at one sample collection time (of two per day, generally taken between 10 am and 12 pm, and 1.00 pm and 2.30 pm, when crowds are at a minimum and maximum, respectively). In contrast, Cabelli and his colleagues (1982) tended to obtain three to four samples, at two or three sites from each beach, at chest depth (approximately four inches below the water surface), at the time of maximum swimming activity (i.e: generally between 11.00 am and 5.00 pm).

It was felt that the sampling procedures adopted in this study could be tested by the collection of a comprehensive set of water samples from a single location at a specific sampling time (with duplicates available for a subset of the samples). Thus, during the summer of 1983, bacteriological samples were collected from Professor's Lake between 1.45 pm and 3.45 pm on August 13th, 14th, and 20th. One extra nearshore, and one extra offshore sample were acquired on August 14th. Approximately the same sample sites were chosen in the swimming area (six) and offshore (six). Locations of samples are given in Figure 3.2.

These data were recast into arithmetic means for nearshore and offshore samples on each sample day. The resulting data and accompanying standard deviations (two sigma values) provide a reasonable estimate of the

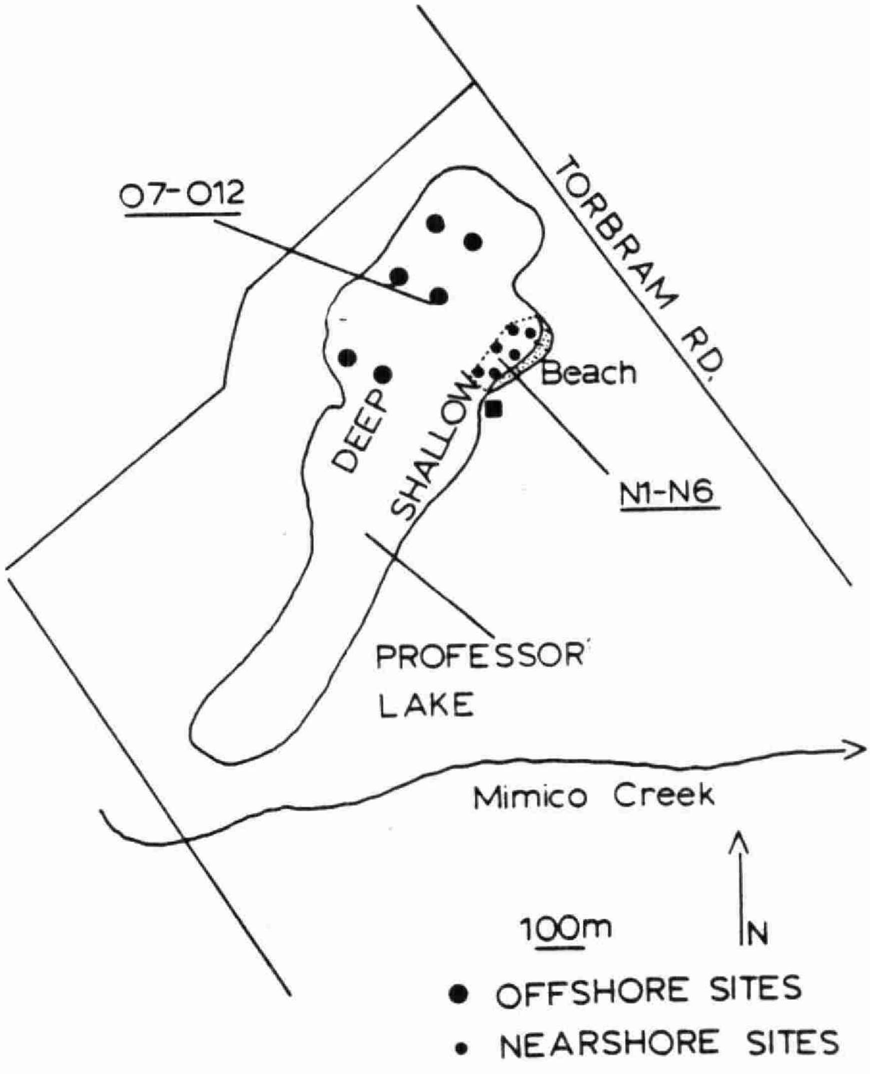

Figure 3.2 Location of Samples Collected at Professor's Lake

variability in bacterial content of nearshore and offshore waters on each of the sample days. The merits of multiple sample collections were considered in contrast to acquisition of single samples (i.e.: collected at site A on the map). Sampling on August 21st was limited to six nearshore sites, each of which was sampled in duplicate. The resulting means and standard deviations of the bacterial counts for each duplicate site, and the mean standard deviation of these figures provides a valuable index of the reproducability of the data.

3.7 Bacterial and elemental concentration data for the Humber River

Three of the six beaches surveyed during the summer of 1983 were located on the Humber River. Thus, it seemed appropriate to conduct a reconaisance investigation into the bacterial and trace element concentrations in the water at various locations along the river and its tributaries. A major goal in this investigation was to attempt to locate potential sources of pollution on the river.

On July 25th, 1983, after a long dry spell of weather, thirty-four surface water samples were obtained from the Humber River at the sites shown on Figure 3.3. On August 29th, 1983, following a wet spell, thirty-three samples were collected (twenty-eight at similar sites). Samples collected on the first day were acquired at locations 25, 26, 27, 29, 33, and 34. Those samples collected only on the

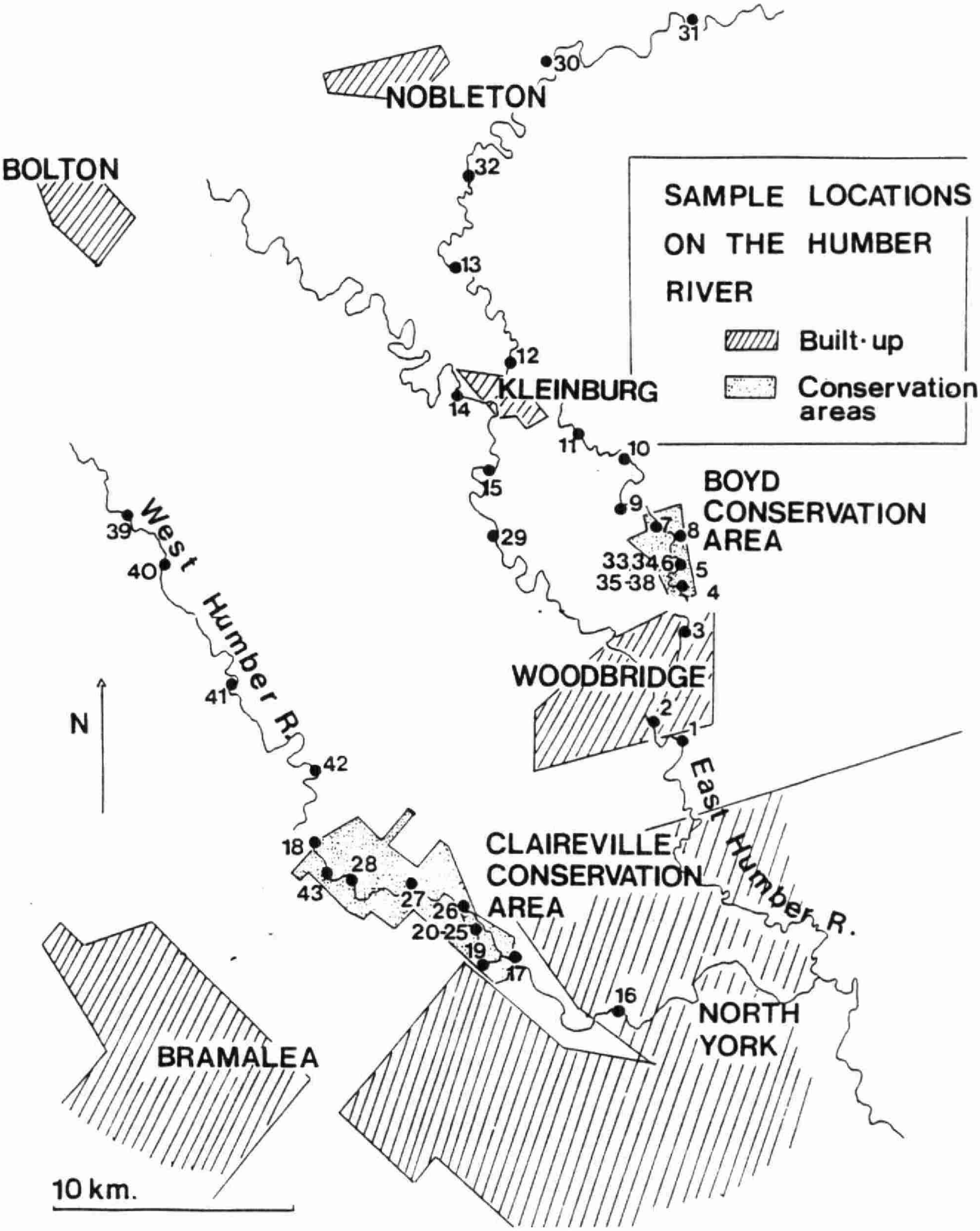

Figure 3.3 Location of Samples Collected on the Humber River

second day were at locations 39, 40, 41, 42, and 43.

Sampling was completed in sterile bottles attached to a 2m aluminum pole, approximately four inches below the water surface. Each water sample was analyzed for the bacteria described in Section 3.3. Trace element analaysis for: P, Ca, Al, Zn, Fe, Mg, S, and Mo was also performed using inductively coupled plasma emission spectrometry. The water samples were filtered through 0.45um Gelman filters and analyzed for trace elements on an ARL 34000 ICP. The analytical conditions used were: a radio frequency of 1200 watts incidence power, a reflective power of 0, observation height of 15 mm using a minhard concentric nebulizer, a cooling gas flow of 12 L per minute, a plasma gas flow of 0.8 L per minute, and a sample uptake rate of 2.6 mL per minute. The trace element analyses were performed at the Institute of Environmental Studies at the University of Toronto (courtesy of J.C. Van Loon).

Arithmetic means and ranges were determined for the bacterial counts on each date. T-tests (Spiegel, 1961) were applied to ascertain whether there was a significant difference between the means on the two days between the twenty eight samples from common locations. In addition, six-point moving averages were calculated using the sixteen common East Humber River locations and the ten common West Humber locations for both of the sample days, to ascertain if there was a coherent trend in the change in bacterial concentrations up- or down-river on each tributary. The common East Humber River locations were 1, 2, 3, 4, 5, 6,

7, 9, 10, 11, 12, 13, 32, 30, and 31. The common West Humber River locations were 16, 17, 19, 20, 21, 22, 23, 24, 28, and 18. At two locations on the main tributary of the river (14, and 15), bacterial and ICP data were collected.

The ICP data were examined, and the arithmetic means were calculated for data which was considered to be above the level of detection of the system, and within the calibration range of the instrument.

3.8 Virological sampling regime and isolation techniques

Virological sampling was undertaken only on Sundays throughout the study period, due to the costs and processing time involved.

The actual virological sampling techniques and primary concentration procedures were outlined previously (The Minstry of Health and Welfare Canada, 1980), however some modifications merit mention. During the primary concentration process, residual water was removed from the filter housings using air pressure, and adsorbed virus was eluted from the filters using freshly prepared 0.05M glycine buffer (pH 10.5 to 11.0). The glycine buffer was adjusted to pH 11.0 prior to adding to the prefilter, but the eluting pH of the buffer would be between 10.5 and 11.0 since any residual liquid in the filter would slightly lower the pH of the added buffer. The glycine buffer was supplemented with 10% tryptose phosphate broth, which

contained 0.0005% phenol red, as a pH indicator. Approximately 800 mL of buffer was passed through the prefilter, and then through the 0.45 um filter. The buffer was permitted to remain in contact with each filter for one to two minutes, and the buffer pH was readjusted to pH 11.0 (with 1N NaOH) following elution of the prefilter and prior to elution of the 0.45 um filter. The buffer was removed from each of the filter housings using positive air pressure. After both filters had been eluted, the eluate was immediately adjusted to pH 7.0 +/-0.2 with 0.05M glycine buffer, which had been adjusted to pH 1.0 with 12N HCl.

For secondary concentration, approximately 1L of eluate from the primary concentration was adjusted to pH 7.0 +/-0.2. Suitable dialysis tubing was then filled with eluate, and both ends of the tubing were securely clamped. The tubing was placed in plastic cakettes, covered with polyethylene glycol (PEG 6000) powder, and dialysis was allowed to proceed at 4^{o} C for 18 +/-2h. When the hydroextraction was complete, the concentrate was filter sterilized through a 0.22 um filter, adjusted to pH 7.6, and inoculated into tissue culture. The tissue culture used was: 1)BS-C-1, 2) RMK (Rhesus Monkey Kidney), and 3) BGM (Buffalo Green Monkey Kidney). The cell cultures were observed microscopically for cytopathic effects for up to 14 days, and were subsequently frozen prior to a second passage (freezing and thawing disruptes cell membranes and aids liberation of virus particles from the cells). Cell

cultures from the first passage were then thawed and pooled, and inoculated into a second set of cell cultures (ie: a second passage). Most samples were passaged three or four times in an attempt to enhance virus replication.

Cell culture lysates were processed for electron microscopy by the agar diffusion method of direct examination (Anderson and Doane, 1973) and by airfuge[R] ultracentrifugation at 90,000rpm onto electron microscopy specimen grids. Samples prepated by both methods were negatively stained with 2% phosphotungstic acid (pH 7.0), prior to examination in a transmission electron microscope. Samples were prepared in duplicate by each method, and at least five grid squares were examined per grid.

CHAPTER 4

MICROBIOLOGICAL AND TRACE ELEMENT RESULTS

4.1 Bacteriological results from the study beaches

4.1.1 Raw bacterial data

The raw bacterial counts are presented by beach, month and date in the Appendix (Table 9.1), along with information concerning air and water temperature.

4.1.2 Correlations between bacteria, and general linear models for these relationships

Correlation coefficients between the various bacterial species ($\log_{10}$ value of bacterial count) generated for the entire data set (open and closed beaches, prior to the calculation of geometric means) by the CORR procedure in SAS (SAS, 1982a,b), as well as the regressions from the GLM procedure in SAS (1982a,b), are provided in Table 4.1.

Colton (1974) suggested that correlations from 0 to 0.25 depict little or no relationship, those from 0.25 to 0.50 indicate a fair degree of relationship, while those between 0.50 to 0.75 depict a moderate to good relationship, and those values in excess of 0.75 indicate a very good to excellent relationship. The correlation coefficients which belong to the last category included *E. coli* versus fecal coliforms (r=0.985), and *P. aeruginosa* on

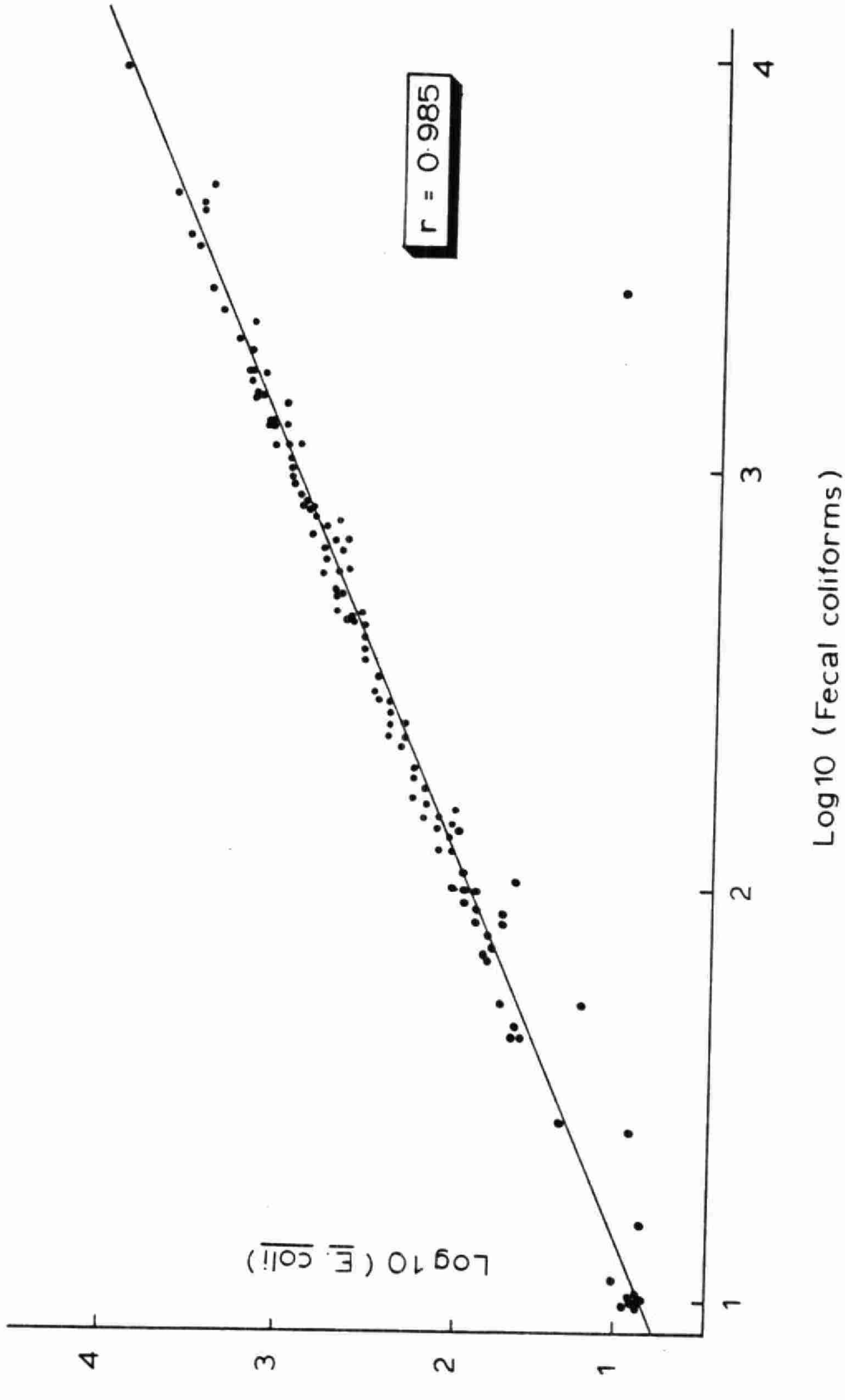

Figure 4.1 GLM (General Linear Model) Regression for E. coli versus Fecal Coliforms

Table 4.1 Bacterial Correlation Coefficients and Results from General Linear Regressions (GLM)

	Heterotrophs	*E. coli*	Fecal coliforms	Enterococci	Fecal streptococci	*P. aeruginosa* (on mPA)	*P. aeruginosa* (on mTIN)	Air temperature	Water temperature
Staphylococci	r=0.244 p=0.0027 n=149	r=0.454 p=0.0001 n=149	r=0.468 p=0.0001 n=149	r=0.367 p=0.0001 n=148	r=0.517 p=0.0001 n=145 Int=0.834 Ho=4.76 pHo=0.0001 se=0.175 Grad=0.641 Ho=7.23 pH=0.0001 se=0.089	r=0.401 p=0.0001 n=151	r=0.387 p=0.0001 n=150	r=0.201 p=0.0133 n=151	r=0.094 p=0.2502 n=151
Heterotrophs		r=0.210 p=0.0086 n=156	r=0.190 p=0.0178 n=156	r=-0.056 p=0.4910 n=155	r=0.285 p=0.0004 n=152	r=0.155 p=0.0519 n=158	r=0.197 p=0.0134 n=157	r=-0.057 p=0.4734 n=158	r= -0.118 p=0.1401 n=158
E. coli			r=0.985 p=0.0001 n=158 Int=-0.075 Ho=-1.97 pHo=0.0503 se=0.038 Grad=1.003 Ho=70.56 pHo=0.0001 se=0.014	r=0.501 p=0.0001 n=156 Int=1.865 Ho=18.23 pHo=0.0001 se=0.102 Grad=0.452 Ho=7.18 pHo=0.0001 se=0.063	r=0.551 p=0.0001 n=154 Int=1.381 Ho=9.47 pHo=0.0001 se=0.146 Grad=0.596 Ho=8.14 pHo=0.0001 se=0.073	r=0.387 p=0.0001 n=158	r=0.371 p=0.0001 n=157	r=0.096 p=0.2283 n=158	r=0.001 p=0.9882 n=158

Table 4.1 Continued

	Heterotrophs	*E. coli*	Fecal coliforms	Enterococci	Fecal streptococci	*P. aeruginosa*	*P. Aeruginosa*	Air temperature	Water temperature
Fecal coliforms				r=0.519 p=0.0001 n=156 Int=1.921 Ho=19.40 pHo=0.0001 se=0.099 Grad=0.460 Ho=7.54 pHo=0.0001 se=0.061	r=0.574 p=0.0001 n=154 Int=1.424 Ho=10.16 pHo=0.0001 se=0.140 Grad=0.609 Ho=8.64 pHo=0.0001 se=0.070	r=0.400 p=0.0001 n=158	r=0.383 p=0.0001 n=157	r=0.099 p=0.2159 n=158	r=0.017 p=0.8330 n=158
Enterococci					r=0.512 p=0.0001 n=154 Int=0.294 Ho=1.75 pHo=0.0816 se=0.168 Grad=0.620 Ho=7.35 pHo=0.0001 se=0.084	r=0.341 p=0.0001 n=157	r=0.327 p=0.0001 n=156	r=0.263 p=0.0009 n=157	r=0.209 p=0.0087 n=157
Fecal streptococci						r=0.395 p=0.0001 n=154	r=0.440 p=0.0001 n=153	r=0.073 p=0.3656 n=154	r=0.051 p=0.5322 n=154

Table 4.1 Continued

	Heterotrophs	<u>E. coli</u>	Fecal coliforms	Enterococci	Fecal streptococci	<u>P. aeruginosa</u>	<u>P. Aeruginosa</u>	Air temperature	Water temperature
<u>P. aeruginosa</u> (mPA)							r=0.785 p=0.0001 n=159 Int=0.170 Ho=3.11 pHo=0.0022 se=0.054 Grad=0.885 Ho=15.87 pHo=0.0001 se=0.056	r=0.179 p=0.0235 n=160	r=0.173 p=0.0285 n=160
<u>P. aeruginosa</u> (mTIN)								r=0.272 p=0.0005 n=159	r=0.257 p=0.0011 n=159

LEGEND:

r=correlation coefficient, p=p>|r| under Ho=rho=0, n=number of observations.
Int=intercept, Ho=t for Ho paramter=0, p=p>|t|, se= standard error of estimate.
Grad=gradient, Ho=t for Ho parameter=0, p=p>|t|, se=standard error of estimate.

mPA versus P. aeruginosa on mTIN (r=0.785).

Correlations which fall between 0.50 and 0.75 (Colton, 1974) include fecal coliforms versus fecal streptococci (r=0.574), E. coli versus fecal streptococci (r=0.551), fecal coliforms versus the enterococci (r=0.519), the total staphylococci versus the fecal streptococci (r=0.517), the enterococci versus the fecal streptococci (r=0.512), and E. coli versus the enterococci (r=0.501). The remaining correlations give values below 0.50.

The GLM regression analysis results are presented for bacterial species which have correlation coefficients in excess of 0.50. The order from highest to lowest value of the slope parameter (m) were: E. coli versus fecal coliforms (m=1.003 - refer to Figure 4.1), P. aeruginosa on mPA versus P. aeruginosa on mTIN (m=0.885), the total staphylococci versus the fecal streptococci (m=0.641), fecal coliforms versus the fecal streptococci (m=0.609), E. coli versus the fecal streptococci (m=0.596), and E. coli versus the enterococci (m=0.452). In contrast, the highest to lowest intercepts (c) were fecal coliforms versus the enterococci (c=1.921), E. coli versus the enterococci (c=1.865), fecal coliforms versus the the fecal streptococci (c=1.424), E. coli versus the fecal streptococci (c=1.381), the total staphylococci versus the fecal streptococci (c=0.294), P. aeruginosa on mPA versus P. aeruginosa on mTIN (c=0.170), and E. coli versus fecal coliforms (c=-0.075).

4.1.3 Correlation between bacterial counts, air temperature, and water temperature

The correlation coefficients between the various bacterial species and both air and water temperatures are listed in Table 4.2. None of the correlation coefficients exceeded 0.28 which indicates that the relationships detected were only marginal at best.

4.1.4 Bacterial geometric means - overall and by status

The overall (i.e: open and closed beaches) bacterial geometric means, and the bacterial geometric means by status (i.e: open versus closed locations) appear in Table 4.3 and Figure 4.2. Examination of these data reveal that:

1. For the overall geometric mean data, the fecal coliform geometric mean (432) greatly surpasses the Canadian and American guidelines of 200 organisms per 100 mL of water (The Ministry of National Health and Welfare, 1983; U.S. Environmental Protection Agency, 1976), as well as the Province of Ontario, Canada, guideline of 100 organisms per 100 mL of water (Ontario Ministry of the Environment, 1978).

2. The fecal coliform geometric means for both open and closed beaches (at densities of 423 and 453, respectively) noticeably exceeded the Canadian and Ontario guideline values.

3. Comparison of open versus closed beaches revealed

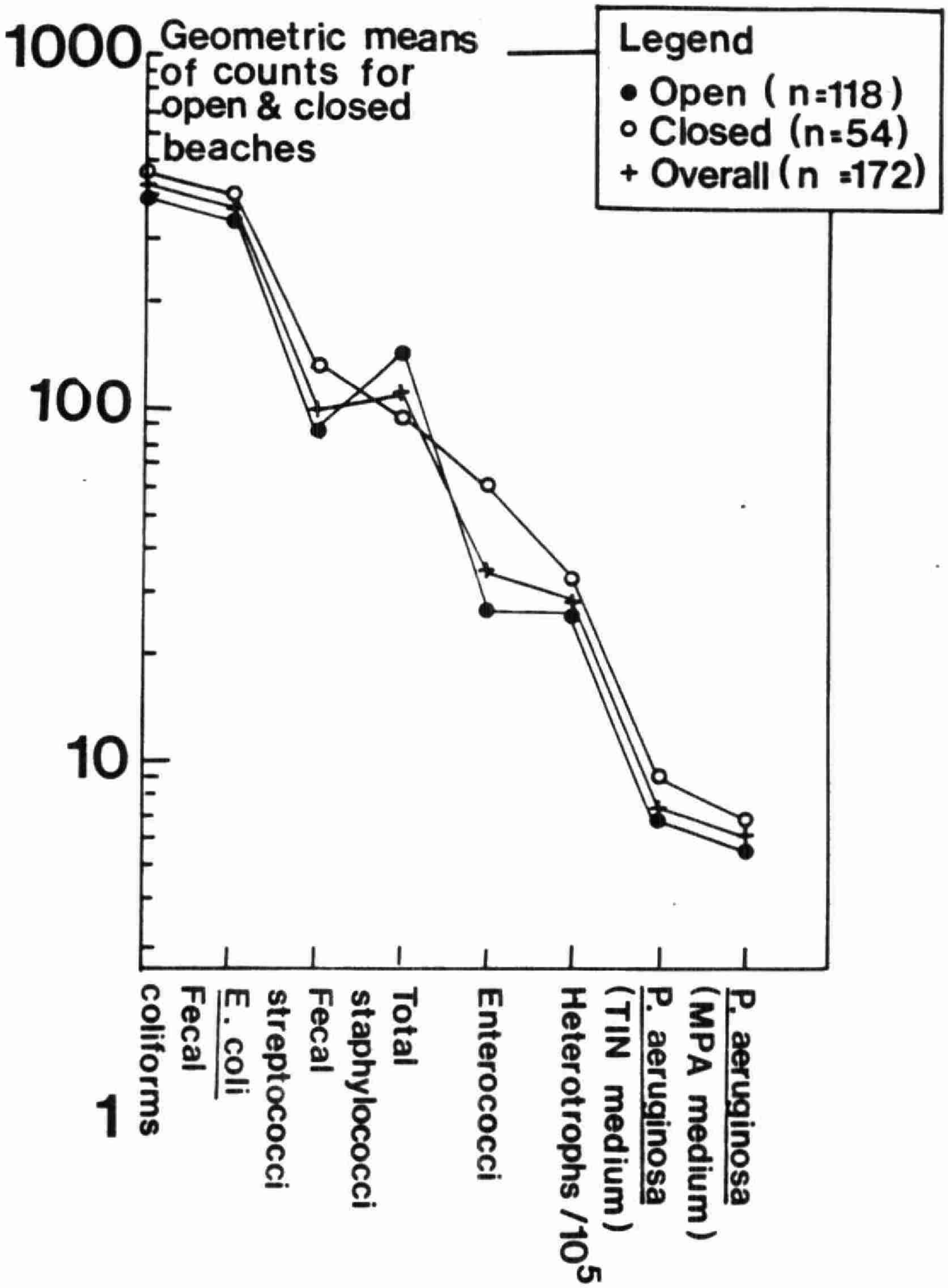

Figure 4.2 Overall Bacterial Geometric Means

Table 4.2 Correlation Coefficient Data for Bacterial Counts ($\log_{10}$) Versus Air and Water Temperature

	AIR TEMPERATURE	WATER TEMPERATURE
Total staphylococci	0.261	0.126
Heterotrophs	-0.094	-0.210
Enterococci	0.236	0.248
Fecal streptococci	-0.057	-0.011
P. aeruginosa (mPA)	0.090	0.163
P. aeruginosa (mTIN)	0.148	0.280
Fecal coliforms	0.050	0.110
E. coli	n.a.	n.a.

Table 4.3 Overall Geometric Means of Bacterial Counts

ORGANISM	GEOMETRIC MEANS (N)		
	Open and Closed Beaches	Open Beaches	Closed Beaches
P. aeruginosa (mPA)	7 (172)	7 (118)	9 (54)
P. aeruginosa (mTIN)	6 (172)	6 (118)	7 (54)
Heterotrophs	2799063 (171)	2589361 (118)	3328985 (53)
Enterococci	35 (172)	27 (118)	61 (54)
Total staphylococci	125 (163)	142 (109)	96 (54)
Fecal streptococci	100 (172)	88 (118)	131 (54)
E. coli	370 (172)	361 (118)	390 (54)
Fecal coliforms	432 (172)	423 (118)	453 (54)

that closing the beaches did not lower the bacterial geometric means (apart from the value for total staphylococci).

4. The E. coli geometric means for the overall data (370), and open (361) and closed (390) beaches were well above the value of 100 organisms per 100 mL of water.

5. The geometric means for the total staphylococci surpassed the value of 100 organisms per 100mL of water, overall (125), and for open (142), but not closed (96) beaches.

6. The presence of the potential opportunistic pathogen, P. aeruginosa (The Ministry of National Health and Welfare, 1983; Hoadley, 1977), was evident overall, and at both open and closed beaches.

4.1.5 Statistical testing of the natural logarithms of the bacterial counts - by status

Statistical tests of the natural logarithms of the bacterial counts are outlined, by status, in Table 4.4. By the LSD (Fisher's Least Significant Difference) multiple comparison test, significantly different comparisons at the 5 % level were detected for only the total staphylococci and the enterococci (only the total staphylococcal value displayed a reduced value at closed beaches). No significant reduction was found for: E. coli, fecal coliforms, fecal streptococci, and P. aeruginosa (on mPA and mTIN).

Table 4.4 Statistical Results from ANOVA (Analysis of variance) Testing Natural Logarithms of the Bacterial Counts (LSD t-test).

STATUS	Open (1)	Closed (2)
Open (1)		A,E
Closed (2)	A,E	

Legend:
A - total staphylococci
B - heterotrophs
C - *E. coli*
D - fecal coliforms
E - enterococci
F - fecal streptococci
G - *P. aeruginosa* (mPA)
H - *P. aeruginosa* (mTIN)

(Only comparisons which are significantly different at the 0.05 level are presented).

4.1.6 Bacterial geometric means - by month

In Table 4.5 and Figure 4.3, the geometric means of the bacterial counts are displayed by month. The data indicate that:

1. The Canadian, American, and Province of Ontario guideline values for fecal coliforms were exceeded in June (310), July (555; highest value), and August (330).

2. The E. coli geometric mean densities were well above 100 mL of water during June (272), July (479; highest value), and August (278).

3. The geometric means for the total staphylococci were greater than 100 organisms per 100mL for June (291; highest value), and July (169), but not August (74).

4. The presence of the potential opportunistic pathogen P. aeruginosa was observed in all three months of the study.

5. The enterococcal geometric mean was highest for July (45), followed by August (41), and June (4), respectively.

6. The fecal streptococcal geometric mean was highest for July (142), followed by June (123), and August (58) respectively.

7. The geometric mean was highest in July for: P. aeruginosa (on mPA and mTIN), the enterococci, fecal streptococci, E. coli, and fecal coliforms, and highest in June for heterotrophs and the total staphylococci.

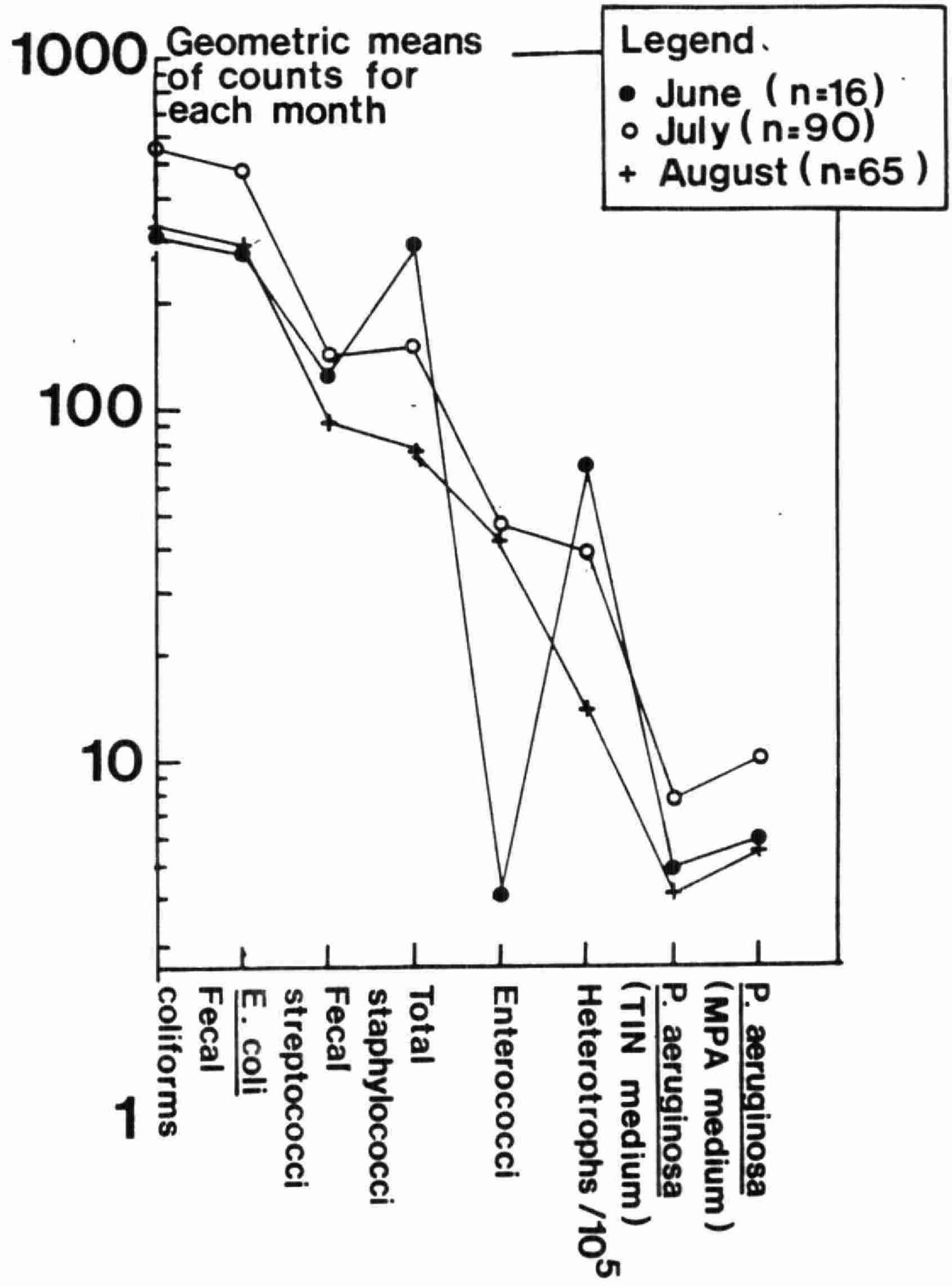

Figure 4.3 Geometric Means of Bacterial Counts by Month

Table 4.5 Geometric Means of bacterial Counts, by Month

ORGANISM	GEOMETRIC MEAN (N)		
	JUNE	JULY	AUGUST
P. aeruginosa (mPA)	5 (16)	10 (91)	6 (65)
P. aeruginosa (mTIN)	6 (16)	8 (91)	4 (65)
Heterotrophs	6990824 (16)	3956978 (91)	1360989 (64)
Enterococci	4 (16)	45 (91)	41 (65)
Total staphylococci	291 (8)	169 (90)	74 (65)
Fecal streptococci	123 (16)	142 (91)	58 (65)
E. coli	272 (16)	479 (91)	278 (55)
Fecal coliforms	310 (16)	555 (91)	330 (65)

4.1.7 Statistical testing of the natural logarithms of the bacterial counts - by month

Statistical test results on the natural logarithms of the bacterial counts are presented by month in Table 4.6. The largest number of significant differences (at the 5 % level) were obtained between July and August, when significant differences were detected for the total staphylococci, heterotrophs, _E. coli_, fecal coliforms, and fecal stretococci. Between June and August, significant differences were observed for the total staphylococci, heterotrophs, enterococci, and fecal streptococci. Significant differences were detected for the enterococci and heterotrophs between June and July.

4.1.8 Bacterial geometric means - by beach

The geometric means of the bacterial counts are displayed by beach in Table 4.7 and Figure 4.4. From these data it is apparent that:

1. The geometric means for the _P. aeruginosa_ on mPA had the following order of highest to lowest density values: Kelso C.A. (Conservation Area), Boyd C.A., Claireville C.A., Heart Lake C.A., and Albion Hills C.A., and Professor's Lake.

2. The geometric means for _P. aeruginosa_ on mTIN displayed the following order of decreasing density: Kelso

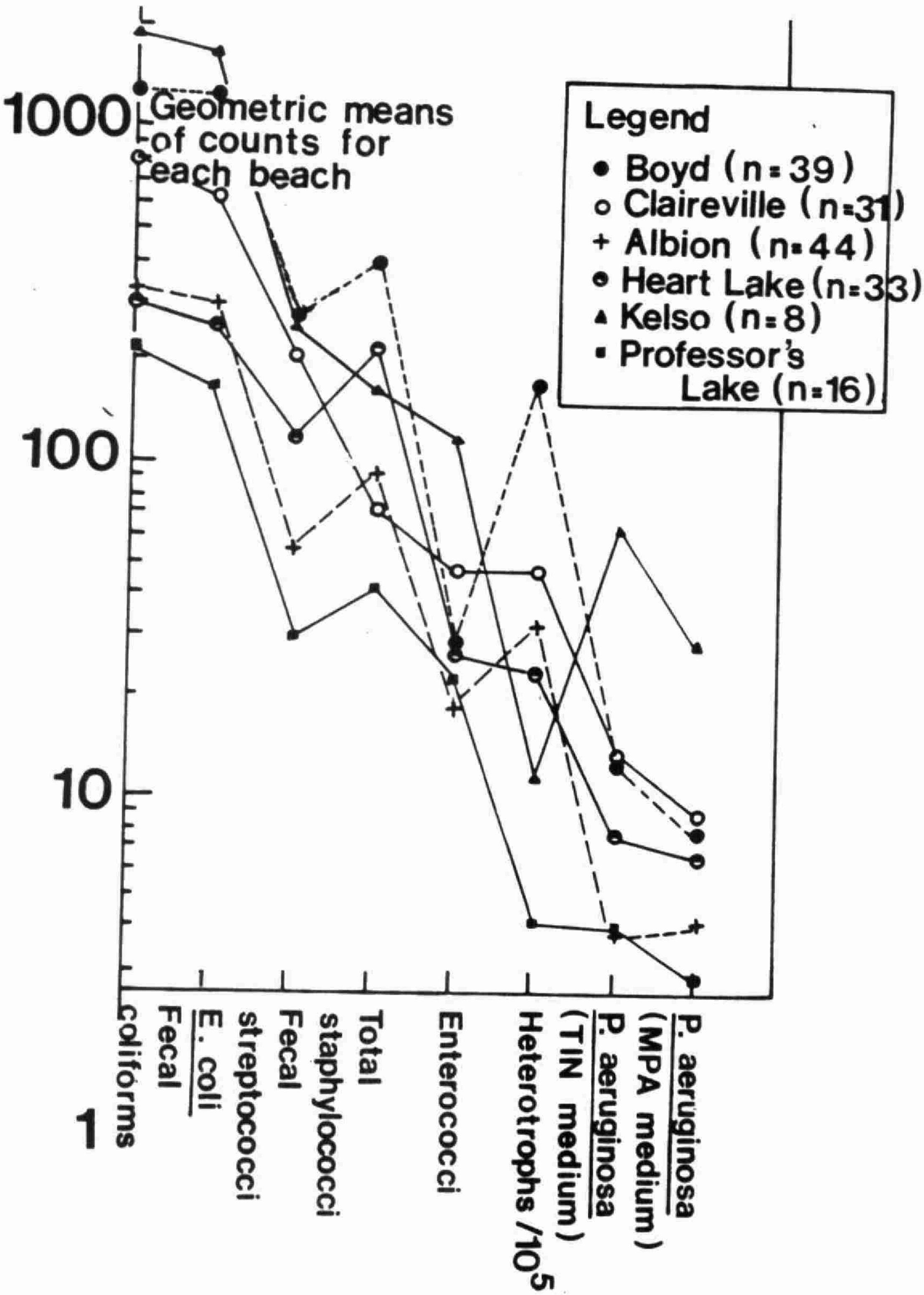

Figure 4.4 Geometric Means of Bacterial Counts by Beach (i.e.: Open and Closed Beaches collectively)

Table 4.6 Statistical Results from ANOVA (LSD t-test) Testing the Natural Logarithms of the Bacterial Counts by Month

MONTH	JUNE (6)	JULY (7)	AUGUST (8)
JUNE (6)		B,E	A,B,E,F
JULY (7)	B,E		A,B,C,D,F
AUGUST (8)	A,B,E,F	A,B,C,D,F	

Legend:
- A - total staphylococci
- B - heterotrophs
- C - *E. coli*
- D - fecal coliforms
- E - enterococci
- F - fecal streptococci
- G - *P. aeruginosa* (mPA)
- H - *P. aeruginosa* (mTIN)

(Only comparisons which are significantly different at the 0.05 level are presented).

Table 4.7 Geometric Means of Bacterial Counts, by Beach (including both open and closed beaches)

BEACH	N	P. aeruginosa (mPA)	P. aeruginosa (mTIN)	Heterotrophs	Enterococci	Total staphylococci	Fecal streptococci	E. coli	Fecal coliforms
(1) BOYD	39	18	11	6033695	37	103	152	443	503
(2) CLAIREVILLE	31	8	6	2407375	72	282	203	794	967
(3) ALBION HILLS	44	4	4	3174590	19	93	55	298	327
(4) HEART LAKE	34	6	5	3216177	39	176	120	224	268
(5) KELSO	8	30	17	1540471	77	180	125	1147	1283
(6) PROFESSOR'S LAKE	16	4	3	412746	22	41	29	163	216

(1)-(5) are Conservation Areas.
For Total staphylococci, N=37,28,42,32,8,16.

C.A., Boyd C.A., Claireville C.A., Heart Lake C.A., Albion Hills C.A., and Professor's Lake. The order displayed by the determinations on mTIN were similar to those determined on mPA.

3. For the heterotrophs, the order of the geometric means from highest to lowest was: Boyd C.A., Heart Lake C.A., Albion Hills C.A., Claireville C.A., Keslo C.A., and Professor's Lake.

4. The order of decreasing values for the enterococcal geometric means was: Kelso C.A., Claireville C.A., Heart Lake C.A., Boyd C.A., Professor's Lake, and Albion Hills C.A.

5. The geometric means for the total staphylococci displayed the following order from highest to lowest: Claireville C.A., Kelso C.A., Heart Lake C.A., Boyd C.A., Albion Hills C.A., and Professor's Lake.

6. For the fecal streptococci, the descending order of the geometric means was: Claireville C.A., Boyd C.A., Kelso C.A., Heart Lake C.A., Albion Hills C.A., and Professor's Lake.

7. The order of the _E. coli_ geometric means in decreasing magnitude was: Kelso C.A., Claireville C.A., Boyd C.A., Albion Hills C.A., Heart Lake C.A., and Professor's Lake.

8. The geometric means for fecal coliforms had the following order of decreasing density: Kelso C.A., Claireville C.A., Boyd C.A., Albion Hills C.A., Heart Lake C.A., and Professor's Lake. This reflected the same order

as for *E. coli*.

9. The geometric mean data indicated that Kelso, Boyd, and Claireville C.A.'s frequently displayed higher bacterial geometric means, whereas Professor's Lake and Albion Hills C.A. tended to display lower geometric mean values. The Heart Lake values varied considerably.

10. The geometric mean guideline values of both 200 and 100 fecal coliforms per 100 mL of water were exceeded at all the beaches.

11. The *E. coli* geometric means surpassed the level of 100 organisms per 100 mL of water at all of the study beaches.

12. The total staphylococcal geometric means were greater than 100 organisms per 100 mL of water at all the study beaches except for Professor's Lake and Albion Hills C.A.

13. *P. aeruginosa*, a potential opportunistic pathogen, was isolated at each of the beaches investigated.

4.1.9 Statistical testing of the natural logarithms of the counts - by beach

In Table 4.8, statistical test results on the natural logarithms of the counts are presented for each beach. The maximum number of significantly different (at the 5 % level) comparisons were detected between: Boyd C.A. and Professor's Lake, and between Kelso C.A. and Professor's Lake. In contrast, the minimum number of significantly

Table 4.8 Statistical Results from ANOVA (LSD t-test) Testing of Natural Logarithms of the Bacterial Counts by Beach

BEACH		BOYD (1)	CLAIREVILLE (2)	ALBION HILLS (3)	HEART LAKE (4)	KELSO (5)	PROFESSOR'S LAKE (6)
BOYD	(1)		A,B,E	B,F,G,H	A,C,D,G	B	A,B,C,D,F,G,H
CLAIREVILLE	(2)	A,B,E		A,C,D,E,F	C,D	G	A,B,C,D,E,F
ALBION	(3)	B,F,G,H	A,C,D,E,F		E,F	C,D,E,G,H	A,B
HEART LAKE	(4)	A,C,D,G	C,D	E,F		C,D,G,H	A,B,F
KELSO	(5)	B	G	C,D,E,G,H	C,D,G,H		A,B,C,D,F,G,H
PROFESSOR'S LAKE	(6)	A,B,C,D,F, G,H	A,B,C,D,E,F	A,B	A,B,F	A,B,C,D,F, G,H	

Legend:
A - total staphylococci
B - heterotrophs
C - _E. coli_
D - fecal coliforms
E - enterococci
F - fecal streptococci
G - _P. aeruginosa_ (mPA)
H - _P. aeruginosa_ (mTIN)

(Only comparisons which are significantly different at the 0.05 level are presented).

different comparisons were observed between: Boyd C.A., and Kelso C.A., and between Claireville C.A. and Kelso C.A. In addition, the following observations were made:

1. For Boyd C.A., the maximum and minimum numbers of significantly different comparisons, respectively, were detected between Boyd C.A. and Professor's Lake, and between Boyd C.A. and Kelso C.A.

2. For Claireville C.A., the above order became Claireville C.A. and Professor's Lake, and Claireville C.A. and Kelso C.A.

3. For Albion Hills C.A., the above order was: Albion Hills C.A. and Claireville C.A., and Albion C.A., and both Heart Lake C.A. and Professor's Lake.

4. For Heart Lake C.A., the maximum and minimum numbers of significantly different comparisons, respectively, were detected between Heart Lake C.A. and Professor's Lake, and between Heart Lake C.A. and both Claireville and Albion Hills C.A.'s.

5. For Kelso C.A., the above order became: Kelso C.A. and Professor's lake, and Kelso C.A. and both Boyd and Claireville C.A.'s.

6. For Professor's Lake, that same order was: Professor's Lake and both Boyd and Kelso C.A.'s, and Professor's Lake and both Albion Hills and Heart Lake C.A.'s.

4.1.10 Bacterial geometric means - by beach and status

The geometric means of the bacterial counts are

depicted by beach and status in Table 4.9. The following remarks apply to these data:

1. For P. aeruginosa on mPA, the geometric means were higher at the open versus the closed beaches for Claireville, Heart Lake, and Kelso C.A.'s, and at the closed versus open beaches for Boyd C.A. The same comments apply for P. aeruginosa on mTIN.

2. For the heterotrophs, the geometric means were more elevated at the open versus closed beaches for Boyd and Claireville C.A.'s, whereas the reverse was true for Heart Lake and Kelso C.A.'s.

3. For the enterococci, the geometric means were higher at the open versus closed beaches for Kelso C.A., whereas for Boyd, Claireville, and Heart Lake the reverse occurred.

4. For the total staphylococci, the geometric means were higher at the open versus closed beaches for Boyd, Claireville, and Heart Lake C.A.'s, in contrast to the situation at Kelso C.A. which was reversed.

5. The fecal streptococcal geometric means were higher at the open versus closed beaches for Boyd and Kelso C.A.'s, whereas the reverse was true for Claireville and Heart Lake C.A.'s.

6. For E. coli, the geometric means were elevated at the open versus closed beaches for: Boyd, Heart Lake, and Kelso C.A.'s, in contrast to the situation at Claireville C.A.

7. The fecal coliform geometric means were higher at

Table 4.9 Geometric Means of Bacterial Counts by Beach and Status

OPEN BEACHES

BEACH	(N)	*P. aeruginosa* (mPA)	*P. aeruginosa* (mTIN)	Heterotrophs	Enterococci	Total staphylococci	Fecal streptococci	*E. coli*	Fecal coliforms
(1) BOYD	10	12	8	16323929	29	391	272	1102	1275
(2) CLAIREVILLE	18	13	9	4563167	46	502	200	624	763
(3) ALBION	44	4	4	3174590	19	93	55	298	327
(4) HEART LAKE	24	7	7	2279226	27	217	116	251	300
(5) KELSO	6	61	27	1100521	116	160	244	1619	1799
(6) PROFESSOR'S LAKE	16	4	3	412746	22	41	29	163	216

For total staphylococci, N=8,15,42,22,6,16

Table 4.9 Continued

CLOSED BEACHES

BEACH	(N)	*P. aeruginosa* (mPA)	(mTIN)	Heterotrophs	Enterococci	Total staphylococci	Fecal streptococci	*E. coli*	Fecal coliforms
(1) BOYD	29	21	13	4280896	40	72	125	324	365
(2) CLAIREVILLE	13	4	4	993127	131	145	206	1107	1343
(3) ALBION	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(4) HEART LAKE	10	3	3	8056505	94	110	127	170	204
(5) KELSO	2	4	4	4224926	22	255	17	408	465
(6) PROFESSOR'S LAKE	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

For heterotrophs, N=29,13,n.a.,9,2,n.a.
n.a. = not applicable

Boyd, Heart Lake, and Kelso C.A.'s whereas the reverse was true for Claireville C.A.

8. Interestingly, the Canadian, American and Province of Ontario fecal coliform guidelines were surpassed by the geometric means enumerated at all the beaches.

9. The total staphylococcal geometric means exceeded 100 organisms per 100 mL of water at all the open beaches except for Albion Hills C.A. and Professor's Lake, and at all the closed beaches except for Boyd C.A.

10. The potential opportunistic pathogen, *P. aeruginosa*, was detected at each of the open and closed beaches.

4.1.11 Statistical testing of the natural logarithms of the bacterial counts - by beach and status

Statistical test results on the natural logarithms of the counts by beach and status are presented in Table 4.10. Significant differences at the 5 % level are evident from the table at several locations for both open and closed beaches.

4.2 Results from Professor's Lake pilot study: implications of bacteriological sampling procedures on the quality of the data obtained

The arithmetic means and associated standard deviations (one sigma), range of values, and geometric

Table 4.10 Statistical Results from ANOVA (LSD t-test) Testing the Natural Logarithms of the Bacterial Counts by Beach and Status

BEACH AND STATUS CODE	11	12	13	14	15	16	21	22	24	25
	BEACH AND STATUS CODE (See Legend)									
11		B	A,B,C,D, F,G	B,C,D,F	B,G	A,B,C,D,F	A,B,C,D,F	B,E	A,C,D	F
12	B		A,C,D,E, F,G	B,C,D	B,G	A,B,C,D, F,G,H	A,D,F	A,B,E,G	A,C,D,G	F
13	A,B,C,D, F,G	A,C,D,E, F,G		A,F	B,C,D,E, F,G,H	A,B,F	A,G,H	B,C,D,E,F	B,E,F	
14	B,C,D,F	B,C,D	A,F		C,D,E,G,H	A,B,F	A,G	B,G,D,E	B,E	F
15	B,G	B,G	B,C,D,E, F,G,H	C,D,E,G,H		A,B,C,D, E,F,G,H	A,B,C,D,F	G,H	B,C,D,G,H	F,G
16	A,B,C,D,F	A,B,C,D, F,G,H	A,B,F	A,B,F	A,B,C,D,E F,G,H		B,F,G,H	A,B,C,D,E F	B,E,F	B
21	A,B,C,D,F	A,D,F	A,G,H	A,G	A,B,C,D,F	B,F,G,H		A,B,C,D, E,F,G	A,B,G,H	F
22	B,E	A,B,E,G	B,C,D,E,F	B,C,D,E	G,H	A,B,C,D, E,F,G	A,B,C,D,E F,G		B,C,D	F
24	A,C,D	A,C,D,G	B,E,F	B,E	B,C,D,G,H	B,E,F	A,B,G,H	D,B,C		F
25	F	F		F	F,G	B	F		F	

Table 4.10 Continued

Legend:
- A - total staphylococci
- B - heterotrophs
- C - _E. coli_
- D - fecal coliforms
- E - enterococci
- F - fecal streptococci
- G - _P. aeruginosa_ (mPA)
- H - _P. aeruginosa_ (mTIN)

(Only comparisons which are significantly different at the 0.05 are presented).

	STATUS	OPEN	CLOSED
BEACH	BOYD	11	21
	CLAIREVILLE	12	22
	ALBION	13	n.a.
	HEART LAKE	14	24
	KELSO	15	25
	PROFESSOR'S LAKE	16	n.a.

Note, Albion and Professor's Lake were never closed.

means are presented in Table 4.11 for all the samples collected on each date from Professor's Lake, those collected nearshore on each date, and those collected offshore on each date. The raw data are given in Table 9.2 of the Appendix. In addition, the data for the sample collected at the site normally tested during the main study are also provided. As expected, the nearshore arithmetic (Figure 4.5) and geometric mean values generally tended to be greater than the offshore values on each of the three sampling days (August 13th, 14th, and 20th). The single exception was the heterotroph value on August 14th. Interestingly, comparisons of the nearshore and offshore arithmetic mean values were not significantly different at the 5 % level (when two standard deviations about the arithmetic means of the samples are compared, they overlap). The same is true when the overall arithmetic mean values are compared to the nearshore or offshore values. It is also apparent that the counts obtained for the sample collected at the normal sampling site are comparable to the arithmetic means for the nearshore samples (they are not significantly different at the 5 % level).

The arithmetic means (Figure 4.6) and associated standard deviations are presented in Table 4.12 for the duplicate samples collected on August 21st. In general, the standard deviations (two sigma) of the arithmetic means for the individual sites where the duplicates were obtained, were smaller than the overall standard deviations of the arithmetic means (exceptions occur for total staphylococci

Table 4.11 Professor's Lake Pilot Study Project

Bacterium	AUGUST 13 - OVERALL STATISTICS LOCATION						NEARSHORE SAMPLES						OFFSHORE SAMPLES						STANDARD
	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	COUNT (n)
Total staphylococci	12	85	91	0	298	26	6	141	89	56	298	121	6	29	51	0	128	5	154 (1)
Heterotrophs	12	1.2	0.70	0.03	2.4	0.8*	6	1.5*	0.7*	0.5	2.5	1.3*	6	0.9*	0.7	0.03	1.7	0.5*	0.5 (1)
Fecal coliforms	12	221	430	0	1543	52	6	398	570	79	1543	216	6	42	75	0	193	13	356 (1)
<u>E. coli</u>	12	178	360	0	1290	38	6	326	478	40	1290	167	6	32	62	0	156	9	268 (1)
Enterococci	12	28	50	0	179	9	6	46	62	8	179	23	6	9	17	0	44	4	46 (1)
Fecal streptococci	12	31	52	0	184	10	6	50	67	7	184	27	6	12	24	0	60	4	48 (1)
<u>P.aeruginosa</u> (mPA)	12	13	15	0	36	5	6	25	12	3	36	19	6	2	3	0	7	2	21 (1)
<u>P.aeruginosa</u>	12	2	2	0	5	2	6	3	2	0	5	2	6	0	0	0	1	1	4 (1)

Table 4.11 Continued

Bacterium	AUGUST 14 - OVERALL STATISTICS LOCATION						NEARSHORE SAMPLES						OFFSHORE SAMPLES						STANDARD
	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	COUNT
Total staphylococci	12	118	84	0	253	66	7	145	93	8	253	99	5	78	64	0	153	56	241 (1)
Heterotrophs	11	10.0	17.7	0.03	58.0	1.8	7	6.3	9.1	0.3	9.7	2.2	4	17.0	28.0	0.03	58.0	1.2	9.7 (1)
Fecal coliforms	12	233	249	0	833	87	7	342	273	41	8333	223	5	80	92	0	225	23	482 (1)
<u>E. coli</u>	12	230	277	0	928	76	7	345	313	24	928	199	5	68	89	0	220	20	516 (1)
Enterococci	12	47	45	0	153	20	7	69	55	4	153	41	5	13	14	0	35	7	67 (1)
Fecal streptococci	12	47	46	0	124	19	7	71	44	9	124	54	5	13	18	0	39	4	94 (1)
<u>P.aeruginosa</u> (mPA)	12	10	10	0	38	7	7	13	11	6	38	11	5	5	4	0	10	4	11 (1)
<u>P.aeruginosa</u> (mTIN)	12	4	4	0	10	3	7	6	3	1	10	5	5	1	3	0	6	1	7 (1)

Table 4.11 Continued

Bacterium	AUGUST 20 - OVERALL STATISTICS						NEARSHORE SAMPLES						OFFSHORE SAMPLES						STANDARD
	LOCATION																		
	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	n	Mean	lsd	Min.	Max.	Geom. mean	COUNT
Total staphylococci	12	30	35	0	117	14	6	34	138	4	117	21	6	27	29	0	66	10	4 (1)
Heterotrophs	12	0.4	0.4	0.02	1.0	0.3	6	0.5	0.4	0.04	1.0	0.3	6	0.4	0.4	0.02	1.0	0.2	0.2 (1)
Fecal coliforms	12	100	164	4	512	26	6	183	206	4	512	67	6	17	23	4	64	10	83 (1)
E. coli	12	95	147	4	444	24	6	169	182	4	4440	55	6	22	35	4	92	11	76 (1)
Enterococci	12	12	18	0	53	4	6	21	22	8	53	9	6	3	4	0	11	2	14 (1)
Fecal streptococci	12	14	23	0	66	4	6	27	28	0	54	11	6	2	2	0	4	2	15 (1)
P. aeruginosa (mPA)	12	2	3	0	11	1	6	3	5	0	11	2	6	0	1	0	1	1	0 (1)
P. aeruginosa (mTIN)	12	2	4	0	14	1	6	3	5	0	11	2	6	1	1	0	2	1	0 (1)

LEGEND:

Heterotrophs presented at 10^6 level.
All zero values were converted to one in the calculations.
The standard nearshore sample was collected about 3m from the shore.
Min.=minimum, Max.=maximum, Geom. mean=Geometric mean, lsd=one standard deviation

Table 4.12 Duplicate Sample Results from Professor's Lake

SAMPLE	Total staphylococci	Mean	lsd	Geom. mean	Heterotrophs	Mean	lsd	Geom. mean
1-1	95	85	14	84	1.6	1.6	0.01	1.6
1-2	75				1.6			
2-1	118	78	57	67	1.4	2.2	1.1	2.1
2-2	38				3.0			
3-1	91	97	8	97	1.5	1.8	0.3	1.8
3-2	103				2.0			
4-1	153	103	71	89	3.6	8.5	7.0	6.9
4-2	52				14			
5-1	208	194	20	193	6	6.0	0.6	5.9
5-2	180				6			
6-1	132	396	373	295	2	11.0	13.0	6.7
6-2	659				2			
Overall	n.a.	159	124	n.d.	n.a.	5.2	4.0	n.d.

SAMPLE	Fecal coliforms	Mean	lsd	Geom. mean	*E. coli*	Mean	lsd	Geom. mean
1-1	109	127	25	125	80	100	28	98
1-2	144				120			
2-1	246	204	59	200	252	208	62	203
2-2	162				164			
3-1	217	271	76	266	176	262	122	247
3-2	325				348			
4-1	851	659	272	630	564	520	62	518
4-2	466				476			
5-1	722	637	120	631	700	686	206	686
5-2	552				672			
6-1	320	456	192	435	312	510	288	470
6-2	592				708			
Overall	n.a.	392	226	n.d.	n.a.	381	225	n.d.

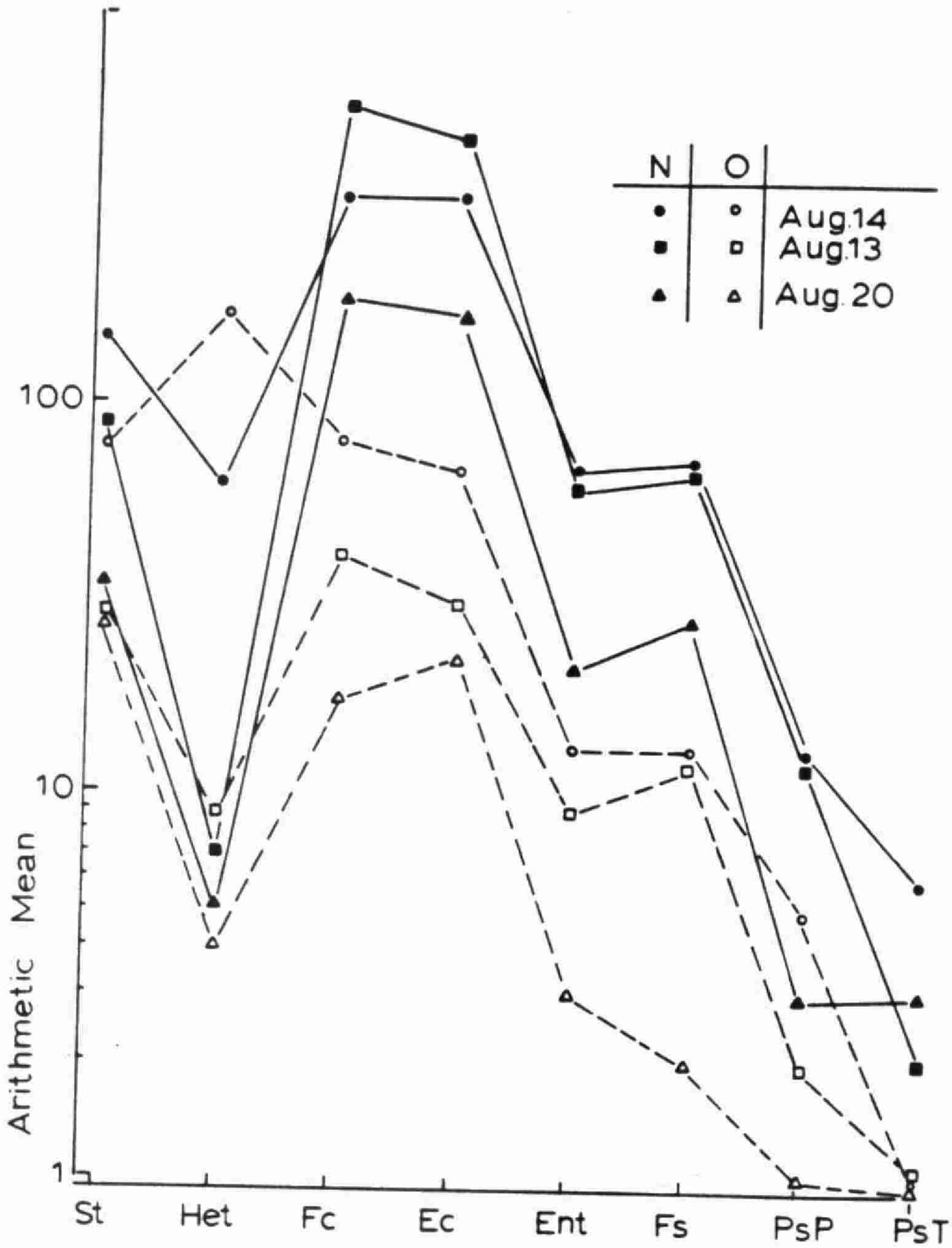

Figure 4.5 Comparison of Arithmetic Means of Professor's Lake - Nearshore versus Offshore Values

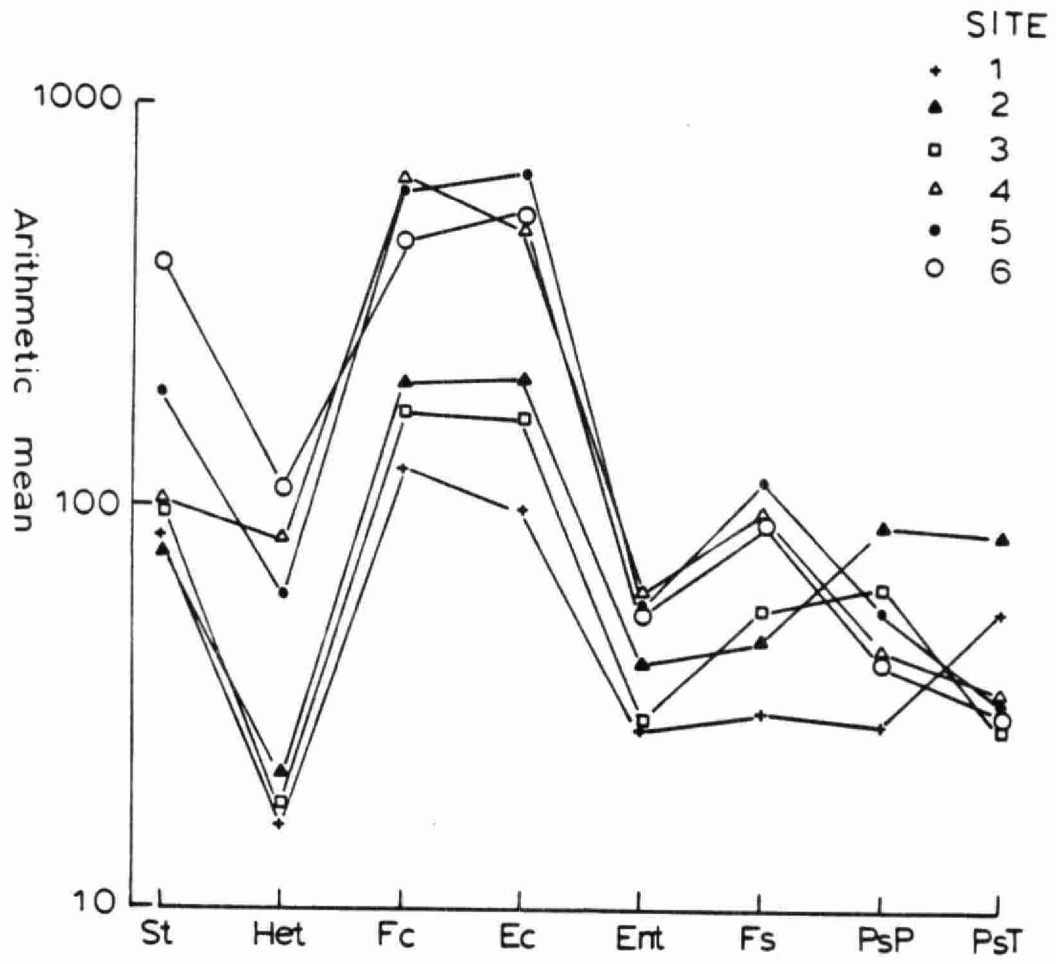

Figure 4.6 Duplicate Sample Arithmetic Means - by Site

Table 4.12 Continued

SAMPLE	Enterococci	Mean	lsd	Geom. mean	Fecal streptococci	Mean	lsd	Geom. mean
1-1	19	28	13	27	21	31	13	47
1-2	37				40			
2-1	41	41	0	41	65	47	25	87
2-2	41				29			
3-1	22	30	11	29	33	56	33	30
3-2	38				79			
4-1	88	64	34	59	98	94	6	33
4-2	40				90			
5-1	47	57	13	56	121	117	6	31
5-2	66				113			
6-1	42	56	20	54	84	95	15	30
6-2	70				105			
Overall	n.a.	46	15	n.d.	n.a.	73	33	n.d.

SAMPLE	*P. aeruginosa*	Mean (mPA)	lsd	Geom. mean	*P. aeruginosa*	Mean (mTIN)	lsd	Geom. mean
1-1	32	29	4	29	84	55	41	47
1-2	26				26			
2-1	82	92	34	91	75	89	52	87
2-2	101				102			
3-1	57	65	11	64	27	30	4	30
3-2	72				33			
4-1	53	46	11	45	47	35	17	33
4-2	38				23			
5-1	59	56	5	55	24	32	11	31
5-2	52				39			
6-1	41	42	1	42	20	32	17	30
6-2	43				44			
Overall	n.a.	55	22	n.d.	n.a.	46	23	n.d.

Legend:
n.a. not available.
All duplicates were performed in the laboratory under blind conditions to provide an adequate test of the laboratory performance.
SAMPLE name is coded xy, where y is either the first or second of the dulpicate pair, and x is:

1 - total staphylococci
2 - heterotrophs
3 - fecal coliforms
4 - *E. coli*
5 - enterococci
6 - fecal streptococci
7 - *P. aeruginosa* (mPA)
8 - *P. aeruginosa* (mTIN)

Arithmetic mean values are given together with one standard deviation. Geom. mean=Geometric mean

at site 6, heterotrophs at sites 4 and 6, fecal coliforms at site 4, E. coli at site 6, enterococci at sites 4 and 6, P. aeruginosa on mPA at site 2, and P. aeruginosa on mTIN at sites 1 and 2. In general, this suggests that there was less variation within one site versus between sites. Consequently, the duplicate data acquired were of acceptable quality. However, due to the apparent differences between sites, multiple sample collection might prove to be of value in water quality sampling.

4.3. Humber River bacterial and trace element study results

The raw bacterial and trace element data are provided in the Appendix (Table 9.3). The arithmetic means and their associated standard deviations (one sigma), as well as the data ranges are outlined in Table 4.13, for the 28 samples common to both sampling days. T-tests applied to the bacterial data detected no significant differences at the 5 % level in corresponding overall bacterial arithmetic means (i.e.: for particular bacteria) between the two sampling days. Six point moving arithmetic bacterial averages for the sixteeen common East Humber locations (subsequently, fifteen points were also used for calculations to exclude a high value at site 5) and four point moving arithmetic means for the ten common West Humber River tributary locations were calculated for both sample days and the resulting data presented in Figures 4.7 to 4.10. The graphs were constructed for all bacteria apart from the

Table 4.13 Statistical Results from Humber River Bacterial and Trace Element Study

BACTERIUM/ELEMENT	n1	mean1	lsd1	min1.	max1.	n2	mean2	lsd2	min1.	max1.
Total staphylococci	28	90	211	7	1115	28	148	265	12	1310
Heterotrophs	28	3.6	3.8	0.3	18.5	28	2.2	1.5	0.6	7.6
Fecal coliforms	28	1624	4700	11	24300	28	1225	1273	79	5470
E. coli	28	1677	4588	4	24100	28	1215	1148	32	6040
Enterococci	28	151	377	13	2020	28	116	94	8	363
Fecal streptococci	28	223	312	39	1672	28	328	242	47	942
P. aeruginosa P	28	3	7	0	29	28	6	9	0	43
P. aeruginosa T	28	2	4	0	22	28	7	9	0	37
(ppm)										
Phosphorus	28	0.3	0.2	0	0.1	28	0.4	0.1	0.2	0.8
Molybdenum	13	0.02	0.01	0.01	0.02	28	0.01	0.01	0.01	0.02
Calcium	28	78	16	49	127	28	67	8	51	89
Aluminium	14	0.04	0.03	0.01	0.08	28	0.09	0.02	0.01	0.14
Zinc	23	0.03	0.02	0.01	0.09	28	0.02	0.01	0.01	0.09
Iron	28	0.04	0.02	0.01	0.07	28	0.02	0.01	0.01	0.05
Magnesium	28	24	3	20	32	28	21	3	17	32
Sulphur	28	15	4	10	26	28	14	3	10	24

Detection limits: P (0.04), Mo (0.005), Ca (0.00007), Al (0.002), Zn (0.002), Fe (0.005), Mg (0.0007), S (0.00002).
Legend: mean=arithmetic mean, lsd=1 standard deviation, max.=maximum.
Days 1 and 2 are prefixed by 1 and 2.

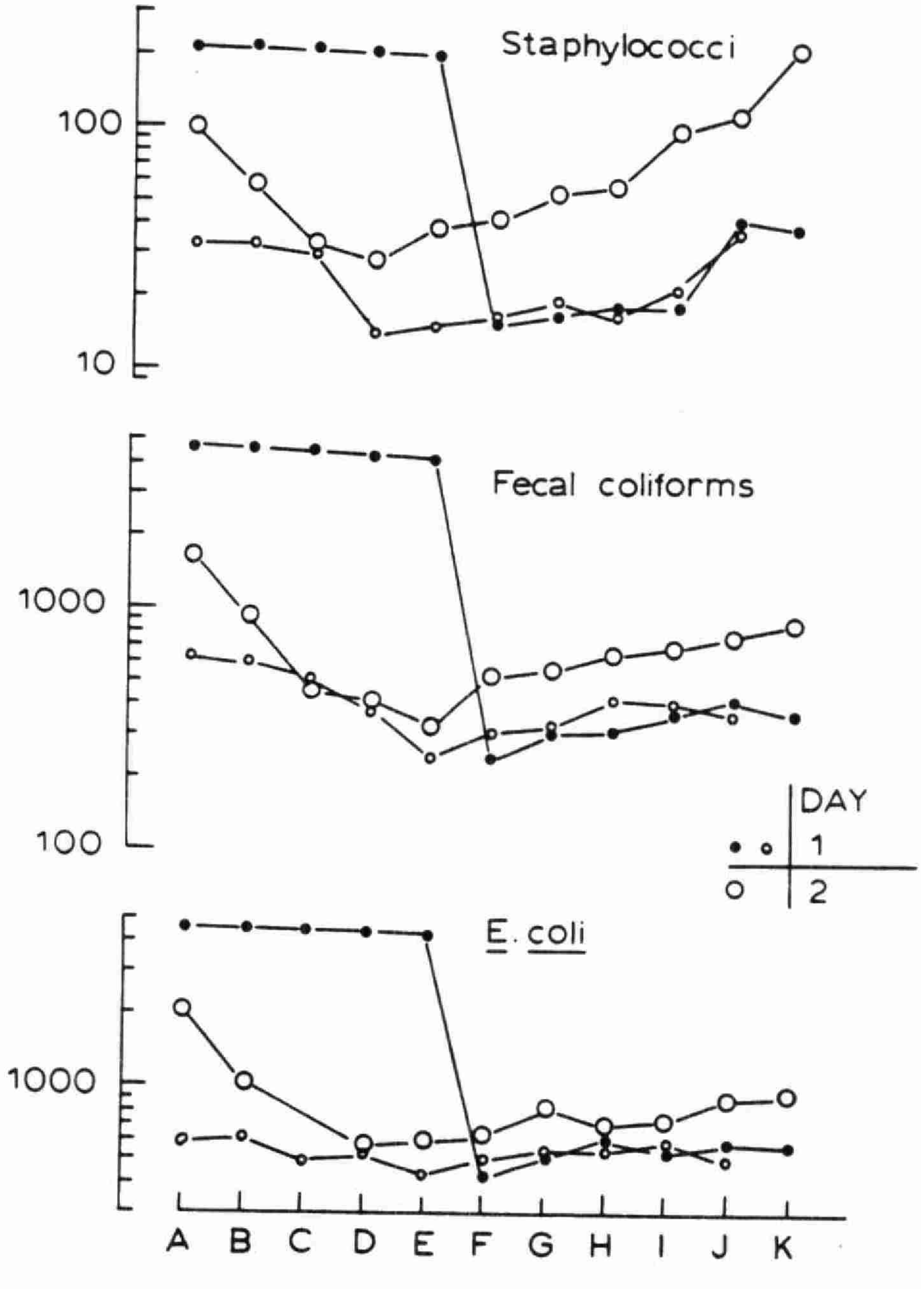

Figure 4.7 Six Point Moving Averages for Total Staphylococci Fecal Coliforms and *E. coli* on the West Humber River

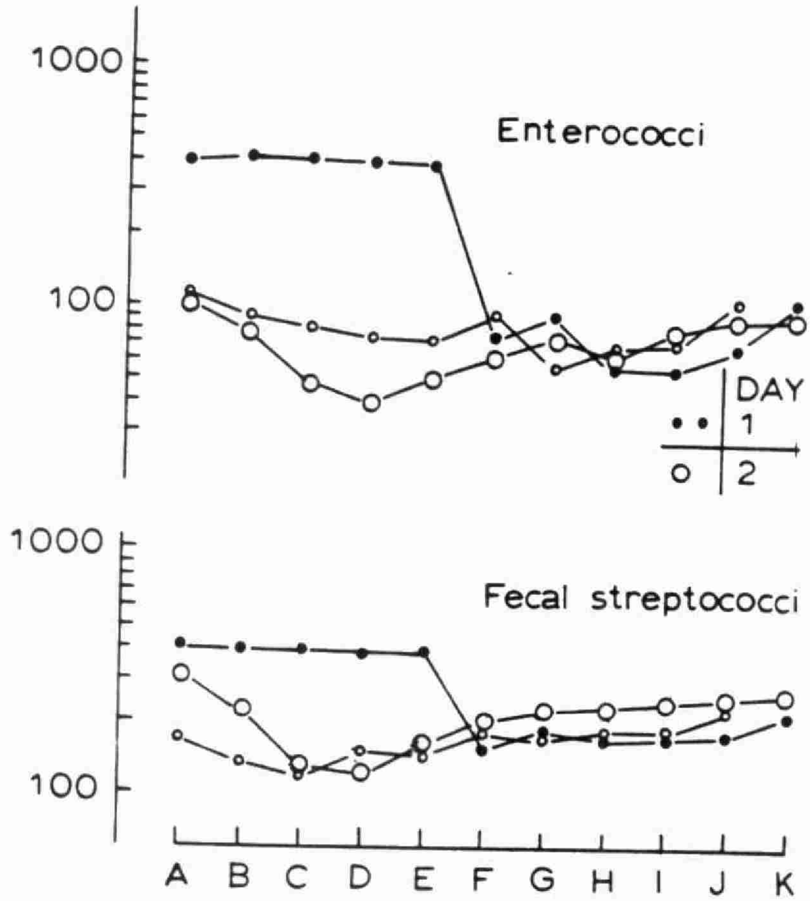

Figure 4.8 Six Point Moving Averages for Enterococci and Fecal Streptococci on the West Humber River

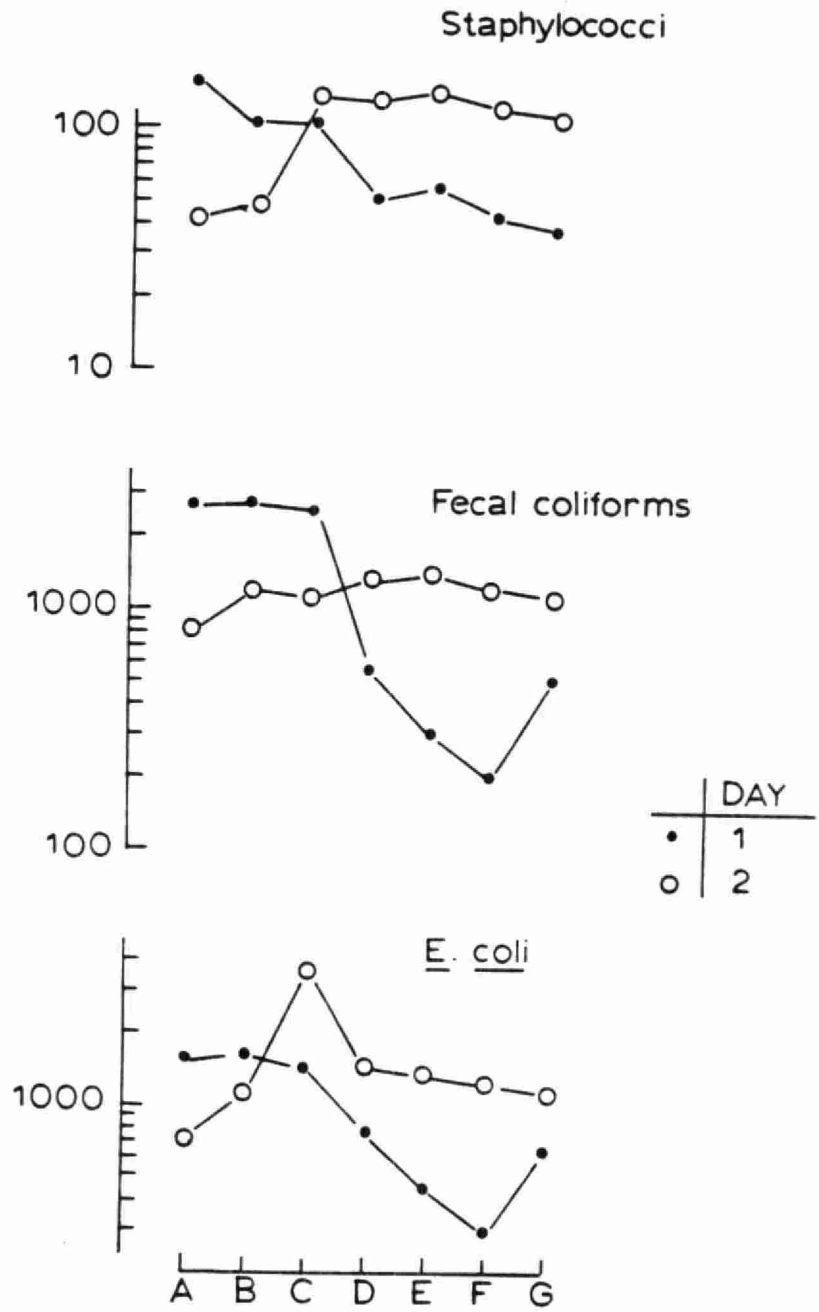

Figure 4.9 Four Point Moving Averages for Total Staphylococci, Fecal Coliforms and *E. coli* on the East Humber River

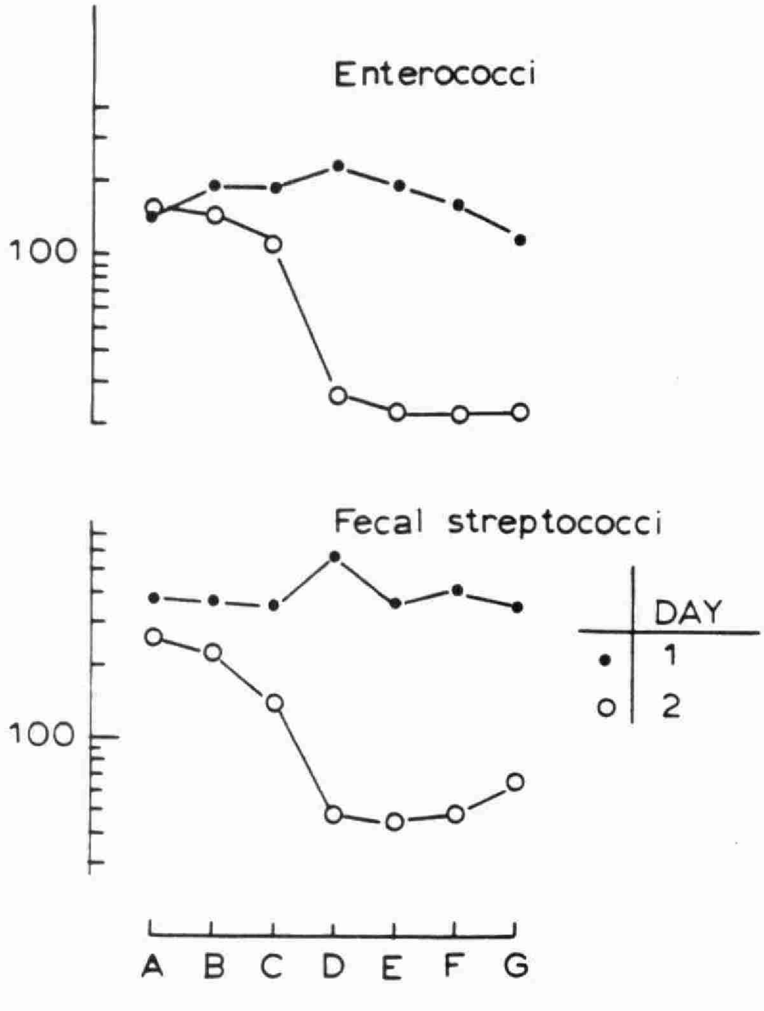

Figure 4.10 Four Point Moving Averages for Enterococci and Fecal Streptococci on the East Humber River

heterotrophs.

Examination of the graphs of moving averages for the East Humber tributary (Figures 4.7 to 4.10) revealed that, in general on both sampling days, higher levels of contamination were apparent near the cities of Woodbridge and King City, that is, in areas of dense human habitation, at both ends of the sampled region of the river. In contrast, agricultural areas between the two cities were associated with lower bacterial concentrations in the river.

The corresponding graphs for the West Humber (Figures 4.7 to 4.10 revealed in general that on July 25th., (i.e. day one) that there was an overall trend of decreasing contamination as one travels up-river to the source. On August 29th (i.e. day two), more variation was evident. For the total staphylococci, the values increased as one proceeded up-river and then levelled off half way up the tributary. For fecal coliforms, little variation occurred as one travelled up river, however a slight rise was evident half way up the tributary. For E. coli, the values increased as one proceeded up river and then declined. Both the enterococci and fecal streptococci displayed little variation as one travels up-river, but a slight rise in mid-river (in agricultural areas) was followed by a slight decline at the source.

The raw and statistical trace element data revealed that high levels of Ca, Mg, and S were detected in the river, in contrast to the other trace elements.

Interestingly, the trace element data provided little variation along the river on either of the sampling days. In addition, there was no striking correlation between bacterial count and trace element concentration (e.g. Figure 4.11) on either sampling day.

4.4 Virological results

No viruses were isolated during the investigation. Unfortunately, severe toxicity problems were encountered during most first tissue culture passages. Most tissue culture cells were dead within three days of inoculation such that the ability of the procedure to recover viruses was greatly impaired. In addition, problems were encountered with the sterilization of the final concentrate through the 0.22um filter, and consequently, numerous first tissue culture passages were contaminated. Attempts to eliminate this contamination were made, but the extent to which it impaired virus recovery is not known.

It has been estimated that the virus recovery procedures are no more than 15 per cent efficient at recovering enteric viruses from environmental water samples (G. Jenkins, pers. comm.). Severe toxicity and contamination problems encountered during this study would have reduced the recovery efficiency even further.

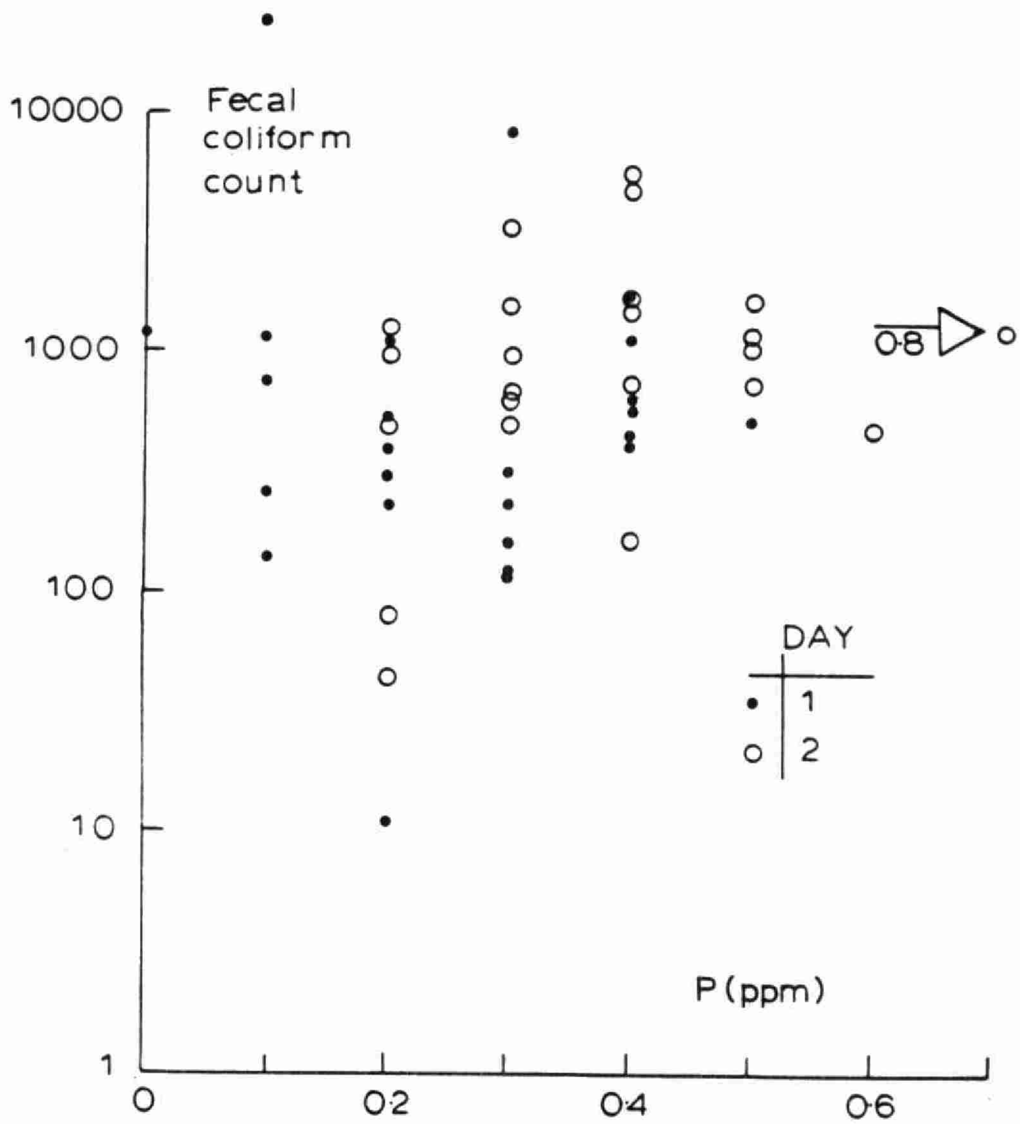

Figure 4.11 Plot of Fecal Coliform Count Per 100 mL of Water versus Phosphorous Content (ppm)

CHAPTER 5

EPIDEMIOLOGICAL METHODS AND PRELIMINARY SURVEY RESULTS

5.1. Epidemiological methods

An interviewer's manual was prepared and used as a basis for instruction. The interviewers were uniformly trained and monitored carefully throughout the entire study. The interviewers wore t-shirts bearing the words: "Health and Water Quality Study", and the insignia the "Province of Ontario", on the front, and the "University of Toronto", on the back.

Fourteen interviewers took part in the study and were rotated between the various study beaches (sample size calculations appear in Section 9.5 of the Appendix). The interviewers were instructed to interview as many beach-goers as possible. A total of 9296 people were interviewed by the interactive interview method at the beaches on weekends, in order to obtain maximum numbers of beach participants (Cabelli et al., 1982). Family units, in contrast to groups of friends, were preferentially selected for interview in order to facilitate the acquisition of accurate and accessible follow-up information. Beach groups of size six or less were considered optimal. During the initial interview, a contact or spokesperson was appointed for each beach group. Ideally, the appointed contact person was the mother of the family because of her perceptive knowledge of family illness. The following information was

collected from each member of the beach group: the relationship to the contact person, age, sex, previous swim record for the past four days, whether the person swam or would swim on the interview day, whether the head was immersed in water, previous or current illness record for the past four days (including: a cold or upper respiratory ailment, ear problems, styes or boils, gastrointestinal problems, allergies, other ailments, and sunburn which was not considered to be an illness). Four days was considered an appropriate period to investigate illness. This was one day longer than the period of illness ascertainment in the case of the follow-up (these periods correspond to those previously used in the study of Seyfried et al., 1985a). In addition, the contact person's telephone number and the best time of day to telephone them were also ascertained at this time. This information was recorded on the "Initial Interview Form" (Appendix, Section 9.6). Confidentiality of the information was emphasized both at the time of the initial interview and at the time of follow-up.

For the follow-up information, an interviewer telephoned the contact person within seven to ten days of the initial interview. The interviewer obtained answers to the questions listed on the "Telephone Follow-up Form" (Appendix, Section 9.7) and recorded the date when any symptoms were first noticed. The telephone questionnaire attempted to ascertain whether illness occurred within three days (for reliable information, exclusion of illnesses with long term incubation periods, and to attempt

to avoid person-to-person transmission of disease within a household, as well as to avoid the problem of excessive numbers of potentially confounding variables) subsequent to swimming at a specified location. The specific symptoms for which information was obtained are listed in Table 5.1. Sunburn was not considered to be an illness due to the fact that the illness data would be overestimated if sunburn was included. The questionnaire also assessed: the symptoms of the illness, whether medical attention was sought as well as the physician's diagnosis, whether the disability resulted in staying home from work and the duration of the period spent at home, and confirmation of the water exposure data. People who swam in alternate or the same locations within four days prior-to, or three days subsequent to, a trial were analyzed by creating a separate factor in the analysis.

The study population consisted of three groups:

1. Persons who did not enter the water (i.e.: not in the water).

2. Persons who did not enter the water beyond knee-depth, at maximum (i.e.: waders).

3. Persons who entered the water beyond knee-depth.

All data were coded directly upon the questionnaire forms at the time of the interview. The coded data was entered directly onto magnetic tape by The University of Toronto Computer Services Data Entry Service.

Quality control procedures were instituted at all stages of the investigation and analysis, and included such

measures as:

1. Listening to interviews being conducted.

2. Checks of all questionnaire forms.

3. Observation of the lengths of time required to complete an interview.

4. Selective telephone call-backs to assure interviews had been conducted.

5. Checks for typographical errors in data entered by the Data Entry Service.

5.2. Study response rate

A response rate of 90% was achieved in the epidemiological survey, as shown in Table 5.2.

5.3. Study population characteristics and crude symptom rates

Various relevant characteristics are listed, by water category, for:

1. The entire study population (n=9296; Tables 5.3 to 5.4).

2. The study population used in logistic regression modelling (i.e.: missing data for variables of interest in the modelling, precluded the use of data for some subjects; n=8420 in logistic regression modelling (Tables 5.5 to 5.6).

3. The persons eliminated from logistic regression

Table 5.1 List of Symptoms Recorded

A.	Sore Throat
B.	Fever
C.	Cold or cough
D.	Runny or stuffed nose
E.	Earache or runny ears
F.	Styes, or red, itchy or watery eyes
G.	Stomachache or nausea
H.	Diarrhea
I.	Vomiting
J.	Boils
K.	Skin rash
L.	Allergic itch, welts or sneezing
M.	Sunburn (not considered an illness)
N.	Other symptoms

Table 5.2 Response Rates Achieved in the Study

Interviewed Subjects

No. persons interviewed	-	10287
No. Completed interviews	-	9296
No. incomplete interviews (no answer, wrong number or telephone not in service)	-	991
Percentage success	-	90.37%

Persons who refused interview

No. persons who refused interview - 1741
No. persons who refused interview:
(broken down by beach)

Boyd C.A.	-	387
Claireville C.A.	-	222
Albion C.A.	-	636
Heart Lake C.A.	-	160
Kelso C.A.	-	114
Professor's Lake	-	222

Note: Albion C.A, was the only location open throughout the entire season. Information was not available for persons who refused interview.
C.A. - Conservation Area

Table 5.3 Age Distribution of Entire Study Population

AGE GROUP	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
0-under5	842	703	73	66	776	66
	9.1%	9.7%	11.0%	4.8%	9.8%	4.8%
5-under10	1167	1086	48	33	1134	33
	12.6%	15.0%	7.2%	2.4%	14.3%	2.4%
10-under15	1071	989	17	65	1006	65
	11.5%	13.6%	2.6%	4.7%	12.7%	4.7%
15-under20	1071	924	40	107	964	107
	11.5%	12.8%	6.0%	7.7%	12.2%	7.7%
20-under25	1287	1008	94	185	1102	185
	13.8%	13.9%	14.1%	13.4%	13.9%	13.4%
25-under30	988	716	100	172	816	172
	10.6%	9.9%	15.0%	12.5%	10.3%	12.5%
30-under35	997	684	116	197	800	197
	10.7%	9.4%	17.4%	14.3%	10.1%	14.3%
35-under40	792	521	78	193	599	193
	8.5%	7.2%	11.7%	14.0%	7.6%	14.0%
40-under45	423	256	43	124	299	124
	4.6%	3.5%	6.5%	9.0%	3.4%	9.0%
45-under50	248	149	21	78	170	78
	2.7%	2.1%	3.2%	5.6%	2.2%	5.6%
50-under55	172	101	13	58	114	58
	1.9%	1.4%	2.0%	4.2%	1.4%	4.2%
55-under60	92	52	9	31	61	31
	1.0%	0.7%	1.4%	2.2%	0.8%	2.2%
60-under65	81	31	10	40	41	40
	0.9%	0.4%	1.5%	2.9%	0.5%	2.9%
65-under70	34	19	1	14	20	14
	0.4%	0.3%	0.2%	1.0%	0.3%	1.0%
70-under75	17	4	2	11	6	11
	0.2%	0.1%	0.3%	0.8%	0.1%	0.8%
75-under80	9	3	0	6	3	6
	0.1%	0%	0%	0.4%	0%	0.4%
80-under85	3	2	0	1	2	1
	0%	0%	0%	0.1%	0%	0.1%
85 and over	2	1	0	1	1	1
	0%	0%	0%	0.1%	0%	0.1%
TOTAL	9296	7249	665	1382	7914	1382
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.1%	14.9%

Table 5.3 Continued

Legend for Tables 5.3 - 5.9

n	CATEGORY
n % of total	n % of category
n 100%	n 100% % of total

Chi-square p-value = 0.0001 for swimmers, waders, and persons who entered the water, and did not enter the water.
Rounding errors in Tables 5.3 to 5.9 may result in summations of greater or less than 100%.

Table 5.4 Demographic and Other Characteristics of Entire Study Population

FACTOR	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
SEX: male	4278	3443	261	574	3704	574
	46.2%	47.7%	39.3%	41.6%	47.0%	41.6%
female	4992	3783	403	806	4186	806
	53.9%	52.4%	60.7%	58.4%	53.1%	58.4%
TOTAL	9270	7226	664	1380	7890	1380
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.1%	14.9%
Chi-square p-value			(0.0001)		(0.0002)	
ITALIAN: yes	2651	2015	175	461	2190	461
	28.7%	27.9%	26.5%	33.5%	27.8%	33.5%
no	6599	5196	486	917	5682	917
	71.3%	72.1%	73.5%	66.6%	72.2%	66.6%
TOTAL	9250	7211	661	1378	7872	1378
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.1%	14.9%
Chi-sqaure p-value			(0.0001)		(0.0001)	
CONTACT PERSON yes	2214	1585	232	397	1817	397
		21.9%	34.9%	28.8%	23.0%	28.8%
no	7059	5647	432	980	6079	980
		78.1%	65.1%	71.2%	77.0%	71.2%
TOTAL	9273	7232	664	1377	7896	1377
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.2%	14.9%
Chi-square p-value			(0.0001)		(0.0001)	
S.E.S. L1	6200	4844	424	932	5268	932
		66.8%	63.8%	67.4%	66.6%	67.4%
L2	1832	1418	150	264	1568	264
		19.6%	22.6%	19.1%	19.8%	19.1%
L3	1264	987	91	186	1078	186
		13.6%	13.7%	13.5%	13.6%	13.5%
TOTAL	9296	7249	665	1382	7914	1382
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.8%	83.1%	14.9%
Chi-square p-value			(0.3939)		(0.7951)	

Classification (similar to Cabelli et al. (1979)):
S.E.S. = socioeconomic status. Bathrooms and kitchens are not counted as rooms.
If person-to-room ratio less than or equal to 0.9, then S.E.S.=L1 (i.e.: high).
If person-to-room ratio greater than 0.9, but less than or equal to 1.3, then S.E.S.=L2 (i.e. middle).
If person to room ratio greater than 1.3, then S.E.S.=L3 (i.e.: low).

Table 5.4 Continued

FACTOR	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
FOOD: 1	684	542	28	114	570	114
	7.4%	7.5%	4.2%	8.3%	7.3%	8.3%
2	4723	3492	362	869	3854	869
	51.2%	48.5%	54.8%	63.6%	49.0%	63.6%
3	1339	1118	95	126	1213	126
	14.5%	15.5%	14.4%	9.2%	15.4%	9.2%
4	2482	2048	176	258	2224	258
	26.9%	28.4%	26.6%	18.9%	28.3%	18.9%
TOTAL	9228	7200	661	1367	7861	1367
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.1%	14.9%
Chi-square p-value			(0.0001)		(0.0001)	
MONTH: 6	1419	1035	131	253	1166	253
	15.3%	14.3%	19.7%	18.3%	14.7%	18.3%
7	5604	4314	344	946	4658	946
	60.3%	59.5%	51.7%	68.5%	58.9%	68.5%
8	2273	1900	190	183	2090	183
	24.5%	26.2%	28.6%	13.2%	26.4%	13.2%
TOTAL	9296	7249	665	1382	7914	1382
	100%	100%	100%	100%	100%	100%
Percentage		78.0%	7.2%	14.9%	85.1%	14.9%
Chi-sqaure p-value			(0.0001)		(0.0001)	

Classification:

Food categories: 1 - no food and/or drink consumed at beach.
2 - food and/or drink brought from home consumed at beach.
3 - food and/or drink bought at beach consumed at beach.
4 - food and/or drink brought from home, and bought at beach, consumed at beach.

Table 5.4 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
BEACH	1	1112	882	69	161	951	161
		12.0%	12.2%	10.4%	11.7%	12.0%	11.7%
	2	1797	1374	118	305	1492	305
		19.3%	19.0%	17.7%	22.1%	18.9%	22.1%
	3	2824	2280	177	367	2457	367
		30.4%	31.5%	26.6%	26.6%	31.0%	26.6%
	4	1713	1127	148	438	1275	438
		18.4%	15.6%	22.3%	31.7%	16.1%	31.7%
	5	480	368	52	60	420	60
		5.2%	5.1%	7.8%	4.3%	5.3%	4.3%
	6	1370	1218	101	51	1319	51
		14.7%	16.8%	15.2%	3.7%	16.7%	3.7%
TOTAL		9296	7249	665	1382	7914	1382
		100%	100%	100%	100%	100%	100%
Percentage			78.0%	7.2%	14.9%	85.1%	14.9%
Chi-square p-value				(0.0001)		(0.0001)	

Classification:

Beach 1 - Boyd C.A. (Conservation Area).
2 - Claireville C.A.
3 - Albion Hills C.A.
4 - Heart Lake C.A.
5 - Kelso C.A.
6 - Professor's Lake.

Table 5.4 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
INTER-VIEWER	1	126	102	0	24	102	24
		1.4%	1.4%	0%	1.7%	1.3%	1.7%
	2	121	70	22	29	92	29
		1.3%	1.0%	3.3%	2.1%	1.2%	2.1%
	3	632	462	51	119	513	119
		6.8%	6.4%	7.7%	8.6%	6.5%	8.6%
	4	940	748	76	116	824	116
		10.1%	10.3%	11.4%	8.4%	10.4%	8.4%
	5	229	179	12	38	191	38
		2.5%	2.5%	1.8%	2.8%	2.4%	2.8%
	6	775	619	26	130	645	130
		8.3%	8.5%	3.9%	9.4%	8.2%	9.4%
	7	1933	1774	106	53	1880	53
		20.8%	24.6%	15.9%	3.8%	23.8%	3.8%
	8	783	594	66	123	660	123
		8.4%	8.2%	9.9%	8.9%	8.3%	8.9%
	9	1126	881	67	178	948	178
		12.1%	12.2%	10.1%	12.9%	12.0%	12.9%
	10	69	51	7	11	58	11
		0.7%	0.7%	1.1%	0.8%	0.7%	0.8%
	11	132	91	17	24	108	24
		1.4%	1.3%	2.6%	1.7%	1.4%	1.7%
	12	811	538	82	191	620	191
		8.7%	7.4%	12.3%	13.8%	7.8%	13.8%
	13	923	664	53	206	717	206
		9.9%	9.2%	8.0%	14.9%	9.1%	14.9%
	14	696	476	80	140	556	140
		7.5%	6.6%	12.0%	10.1%	7.0%	10.1%
TOTAL		9296	7249	665	1382	7914	1382
		100%	100%	100%	100%	100%	100%
Percentage			78.0%	7.2%	14.9%	85.1%	14.9%
Chi-square p-value				(0.0001)		(0.0001)	

Table 5.4 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
NEWSBA	1	3330	2962	157	211	3119	211
		35.8%	40.9%	23.6%	15.3%	39.4%	15.3%
	2	5966	4287	508	1171	4795	1171
		64.2%	59.1%	76.4%	84.7%	60.6%	84.7%
TOTAL		9296	7249	665%	1382	7914	1382
		100%	100%	100%	100%	100%	100%
Percentage			78.0%	7.2%	14.9%	85.1%	14.9%
Chi-square p-value				(0.0001)		(0.0001)	
FOR ILL PEOPLE:							
DR:	1	73	68	2	3	70	3
		11.7%	11.9%	7.7%	10.7%	11.7%	10.7%
	2	551	502	24	25	526	25
		83.3%	88.1%	92.3%	89.3%	88.3%	89.3%
TOTAL		624	570	26	28	596	28
		100%	100%	100%	100%	100%	100%
Percentage			91.3%	4.2%	4.5%	95.5%	4.5%
Chi-square p-value				(0.7923)		(0.8683)	
FOR ILL PEOPLE:							
HOME:	1	41	39	0	2	39	2
		6.6%	6.8%	0%	7.1%	6.5%	7.1%
	2	583	531	26	26	557	26
		93.4%	93.2%	100%	92.9%	93.5%	92.9%
TOTAL		624	570	26	28	596	28
		100%	100%	100%	100%	100%	100%
Percentage			91.3%	4.2%	4.5%	95.5%	4.5%
Chi-square p-value				(0.3871)		(0.9006)	

Classification:

If NEWSBA=1, then the person went swimming or into the water within 4 days before, or 3 days after going to the beach.
If NEWSBA=2, then the person did not do either of the above.
If DR=1, then person visited the doctor.
If DR=2, did not visit the doctor.
If HOME=1, then person stayed home.
If HOME=2, then person did not stay at home.

Table 5.4 Continued

SWIMMERS (Complete data set):		
Swallowed water:	yes	1880 26.0%
	no	5343 74.0%
	TOTAL	7223 100%
Put head in water:	yes	6006 82.9%
	no	1241 17.1%
	TOTAL	7247 100%

Table 5.5 Age Distribution of Study Population Used in Logistic Regression Modelling

AGE GROUP	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
0-under5	8.9%	9.5%	10.2%	4.8%	9.5%	4.8%
5-under10	12.7%	15.0%	7.7%	2.1%	14.4%	2.1%
10-under15	11.6%	13.7%	2.5%	4.6%	12.8%	4.6%
15-under20	11.7%	12.8%	5.8%	8.3%	12.2%	8.3%
20-under25	13.8%	14.0%	12.8%	13.2%	13.9%	13.2%
25-under30	10.5%	9.8%	15.0%	12.1%	10.2%	12.1%
30-under35	10.7%	9.5%	17.6%	14.1%	10.1%	14.1%
35-under40	8.6%	7.3%	12.0%	14.2%	7.7%	14.2%
40-under45	4.6%	3.6%	7.2%	9.1%	3.9%	9.1%
45-under50	2.7%	2.0%	3.7%	5.5%	2.2%	5.5%
50-under55	1.9%	1.4%	2.1%	4.5%	1.5%	4.5%
55-under60	0.9%	0.7%	1.2%	2.1%	0.8%	2.1%
60-under65	0.8%	0.4%	1.8%	2.8%	0.5%	2.8%
65-under70	0.3%	0.2%	0.2%	1.1%	0.2%	1.1%
70-under75	0.2%	0%	0.4%	0.8%	0.1%	0.8%
75-under80	0.1%	0.1%	0%	0.5%	0%	0.5%
80-under85	0%	0%	0%	0.1%	0%	0.1%
85 and over	0%	0%	0%	0.1%	0%	0.1%
TOTAL	8420 100%	6653 100%	574 100%	1193 100%	7227 100%	1193 100%
Percentage		79.1%	6.8%	14.2%	85.8%	14.2%

Chi-square p-value = 0.0001.

Table 5.6 Demographic and Other Characteristics of Study Population used in Logistic Regression Modelling

FACTOR	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
SEX: male	46.4%	47.8%	38.5%	42.3%	47.1%	42.3%
female	53.6%	52.2%	61.5%	57.8%	52.9%	57.8%
TOTAL	8420	6653	574	1193	7227	1193
	100%	100%	100%	100%	100%	100%
Percentage		79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value			(0.0001)		(0.0019)	
ITALIAN: yes	29.2%	28.2%	26.9%	35.7%	28.1%	35.7
no	70.8%	71.8%	73.1%	64.3%	71.9%	64.3
TOTAL	8420	6653	574	1193	7227	1193
	100%	100%	100%	100%	100%	100%
Percentage		79.1%	6.8%	14.2%	85.8%	14.2%
Chi-sqaure p-value			(0.0001)		(0.0001)	
CONTACT PERSON yes	23.7%	21.9%	35.9%	28.4%	23.0%	28.4%
no	76.3%	78.2%	64.2%	71.6%	77.1%	71.6%
TOTAL	8420	6653	574	1193	7227	1193
	100%	100%	100%	100%	100%	100%
Percentage		79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value			(0.0001)		(0.0001)	
S.E.S. L1	66.6%	66.7%	62.9%	67.9%	66.4%	67.9%
L2	19.8%	19.7%	23.0%	18.7%	19.9%	18.7%
L3	13.7%	13.7%	14.1%	13.4%	13.7%	13.4%
TOTAL	8420	6653	574	1193	7227	1193
	100%	100%	100%	100%	100%	100%
Percentage		79.2%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value			(0.2508)		(0.5457)	

Classification (similar to Cabelli et al. (1979)):
S.E.S. = socioeconomic status. Bathrooms and kitchens are not counted as rooms.
If person-to-room ratio less than or equal to 0.9, then S.E.S.=L1 (i.e.: high).
If person-to-room ratio greater than 0.9, but less than or equal to 1.3, then S.E.S.=L2 (i.e. middle).
If person to room ratio greater than 1.3, then S.E.S.=L3 (i.e.: low).

Table 5.6 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
FOOD:	1	7.4%	7.6%	4.6%	7.3%	7.4%	7.3%
	2	51.0%	48.2%	54.8%	64.8%	48.7%	64.8%
	3	14.8%	15.8%	14.2%	9.5%	15.7%	9.5%
	4	26.9%	28.4%	26.4%	18.4%	28.3%	18.4%
TOTAL		8420	6653	574	1193	7227	1193
		100%	100%	100%	100%	100%	100%
Percentage			79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value			----------(0.0001)---------			-----(0.0001)------	
MONTH:	6	8.9%	8.9%	9.5%	8.3%	9.0%	8.3%
	7	64.5%	62.9%	57.5%	76.8%	62.5%	76.8%
	8	26.6%	28.1%	33.0%	14.9%	28.5%	14.9%
TOTAL		8420	6653	574	1193	7227	1193
		100%	100%	100%	100%	100%	100%
Percentage			79.1%	6.8%	14.2%	85.8%	14.2%
Chi-sqaure p-value			----------(0.0001)---------			-----(0.0001)------	

Classification:
Food categories: 1 - no food and/or drink consumed at beach.
2 - food and/or drink brought from home consumed at beach.
3 - food and/or drink bought at beach consumed at beach.
4 - food and/or drink brought from home, and bought at beach, consumed at beach.

Table 5.6 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
BEACH	1	12.4%	12.5%	10.7%	12.7%	12.3%	12.7%
	2	17.2%	17.2%	14.6%	19.0%	17.0%	19.0%
	3	31.4%	32.3%	26.9%	28.4%	31.9%	28.4%
	4	17.3%	14.6%	20.9%	30.5%	15.1%	30.5%
	5	5.6%	5.3%	9.1%	5.0%	5.6%	5.0%
	6	16.1%	18.1%	17.8%	4.3%	18.1%	4.3%
TOTAL		8420	6653	574	1193	7227	1193
		100%	100%	100%	100%	100%	100%
Percentage			79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value			----------(0.0001)---------			-----(0.0001)------	

Classification:

Beach 1 - Boyd C.A. (Conservation Area).
2 - Claireville C.A.
3 - Albion Hills C.A.
4 - Heart Lake C.A.
5 - Kelso C.A.
6 - Professor's Lake.

Table 5.6 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
INTER-VIEWER	1	1.0%	1.0%	0%	1.3%	0.9%	1.3%
	2	1.4%	1.1%	3.5%	2.4%	1.3%	2.4%
	3	6.8%	6.3%	8.1%	9.3%	6.4%	9.3%
	4	10%	10.4%	11.1%	7.5%	10.4%	7.5%
	5	2.5%	2.5%	2.1%	3.0%	2.5%	3.0%
	6	8.3%	8.5%	4.6%	9.0%	8.2%	9.0%
	7	21.4%	25.1%	15.3%	3.2%	24.4%	3.2%
	8	8.4%	8.0%	10%	9.4%	8.2%	9.4%
	9	12.3%	12.3%	10%	13.1%	12.2%	13.1%
	10	0.8%	0.8%	1.2%	0.8%	0.8%	0.8%
	11	1.0%	0.8%	1.6%	1.4%	0.9%	1.4%
	12	8.9%	7.4%	13.2%	15.4%	7.8%	15.4%
	13	10%	9.2%	9.3%	14.6%	9.2%	14.8%
	14	7.3%	6.7%	10%	9.4%	6.9%	6.4%
TOTAL		8420 100%	6653 100%	574 100%	1193 100%	7227 100%	1193 100%
Percentage			79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value				(0.0001)		(0.0001)	

Table 5.6 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
NEWSBA	1	36.0%	40.9%	23.4%	14.7%	39.5%	14.7%
	2	64.0%	59.1%	76.6%	85.3%	60.5%	85.3%
TOTAL		8420	6653	574	1193	7227	1193
		100%	100%	100%	100%	100%	100%
Percentage			79.1%	6.8%	14.2%	85.8%	14.2%
Chi-square p-value				(0.0001)		(0.0001)	
FOR ILL PEOPLE:							
DR:	1	11.6%	12.19%	4.2%	8.7%	11.8%	8.7%
	2	88.4%	87.9%	95.8%	91.3%	88.2%	91.4%
TOTAL		558	511	24	23	535	23
		100%	100%	100%	100%	100%	100%
Percentage			91.6%	4.3%	4.1%	95.9%	4.1%
Chi-square p-value				(0.4500)		(0.6521)	
FOR ILL PEOPLE:							
HOME:	1	1.8%	7.0%	0%	8.7%	6.7%	8.7%
	2	93.2%	93.1%	100%	91.3%	93.3%	91.3%
TOTAL		558	511	24	23	535	23
		100%	100%	100%	100%	100%	100%
Percentage			91.6%	4.4%	4.1%	95.9%	4.1%
Chi-square p-value				(0.3794)		(0.7139)	

Classification:

If NEWSBA=1, then the person went swimming or into the water within 4 days before, or 3 days after going to the beach.
If NEWSBA=2, then the person did not do either of the above.
If DR=1, then person visited the doctor.
If DR=2, did not visit the doctor.
If HOME=1, then person stayed home.
If HOME=2, then person did not stay at home.

Table 5.6 Continued

SWIMMERS (population used in regression modelling):		
Swallowed water:	yes	25.4%
	no	74.6%
	TOTAL	6653 100%
Put head under water:	yes	83.1%
	no	16.9%
	TOTAL	6653 100%

Table 5.7 Age Distribution of Persons Eliminated from Logistic Regression Models

AGE GROUP	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
0-under5	11.1%	12.4%	15.6%	4.8%	12.8%	4.8%
5-under10	11.3%	14.8%	4.2%	4.2%	13.3%	4.2%
10-under15	10.5%	13.4%	3.1%	5.3%	12.0%	5.3%
15-under20	9.9%	12.2%	7.3%	4.2%	11.5%	4.2%
20-under25	14.4%	13.2%	21.9%	14.3%	14.4%	14.3%
25-under30	11.9%	10.3%	15.6%	14.8%	11.1%	14.8%
30-under35	11.1%	8.8%	16.7%	15.3%	9.9%	15.3%
35-under40	8.0%	6.1%	10.4%	12.7%	6.7%	12.7%
40-under45	3.8%	2.7%	2.1%	7.9%	2.6%	7.9%
45-under50	2.9%	2.2%	0%	6.4%	1.9%	6.4%
50-under55	1.4%	1.2%	1.0%	2.1%	1.2%	2.1%
55-under60	1.5%	0.9%	0%	3.2%	1.0%	3.2%
60-under65	1.4%	0.9%	0%	3.7%	0.7%	3.7%
65-under70	0.6%	0.7%	0%	0.5%	0.6%	0.5%
70-under75	0.3%	0.3%	0%	0.5%	0.3%	0.5%
75-under80	0%	0%	0%	0%	0%	0%
80-under85	0%	0%	0%	0%	0%	0%
85 and over	0%	0%	0%	0%	0%	0%
TOTAL	876	596	91	189	687	189
	100%	100%	100%	100%	100%	100%
Percentage		67.4%	11.0	21.6%	78.4%	21.6%

Chi-square p value = 0.0001.

Table 5.8 Demographic and Other Characteristics of Persons Eliminated in Logistic Regression Models

FACTOR	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
SEX: male	43.7%	45.7%	44.2%	37.4%	45.5%	34.4
female	56.3%	54.3%	55.8%	62.6%	54.5%	62.6
TOTAL	845	567	91	187	658	187
	100%	100%	100%	100%	100%	100%
Percentage		66.8%	11.2	22.0%	78.0%	22.0%
Chi-square p-value			(0.1424)		(0.0505)	
ITALIAN:yes	23.4%	24.8%	23.9%	18.9%	24.7%	18.9
no	76.6%	75.2%	76.1%	81.1%	75.3%	81.1
TOTAL	828	552	91	185	643	185
	100%	100%	100%	100%	100%	100%
Percentage		66.6%	11.1%	22.3%	77.7%	22.3%
Chi-sqaure p-value			(0.2585)		(0.1023)	
CONTACT yes	25.4%	22.7%	29.5%	31.5%	23.7%	31.5%
PERSON no	74.7%	77.3%	70.5%	68.5%	76.4%	68.5%
TOTAL	848	573	91	184	664	184
	100%	100%	100%	100%	100%	100%
Percentage		67.3%	11.2	21.6%	78.4%	21.6%
Chi-square p-value			(0.0350)		(0.0298)	
S.E.S. L1	67.8%	68.6%	68.8%	64.6%	68.7%	64.6%
L2	19.3%	18.5%	19.8%	21.7%	18.7%	21.7%
L3	12.9%	12.9%	11.5%	13.8%	12.7%	13.8%
TOTAL	876	596	91	189	687	189
	100%	100%	100%	100%	100%	100%
Percentage		67.4%	11.0	21.6%	78.4%	21.6%
Chi-square p-value			(0.8422)		(0.5467)	

Classification (similar to Cabelli et al. (1979)):
S.E.S. = socioeconomic status. Bathrooms and kitchens are not counted as rooms.
If person-to-room ratio less than or equal to 0.9, then S.E.S.=L1 (i.e.: high).
If person-to-room ratio greater than 0.9, but less than or equal to 1.3, then S.E.S.=L2 (i.e. middle).
If person to room ratio greater than 1.3, then S.E.S.=L3 (i.e.: low).

Table 5.8 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
FOOD:	1	8.1%	6.7%	2.2%	15.5%	6.0%	15.5%
	2	52.9%	51.9%	54.4%	55.2%	52.3%	55.2%
	3	11.8%	12.6%	15.2%	7.5%	13.0%	7.5%
	4	27.3%	28.8%	28.3%	21.8%	28.8%	21.8%
TOTAL		807	541	91	174	633	174
		100%	100%	100%	100%	100%	100%
Percentage			67.0%	11.4	21.5%	78.4%	21.6%
Chi-square p-value			----------(0.0005)---------			-----(0.0001)------	
MONTH:	6	76.6%	74.6%	80.2%	81.5%	75.3%	81.5%
	7	19.6%	21.0%	17.7%	15.9%	20.7%	15.9%
	8	3.8%	4.4%	2.1%	2.7%	4.1%	2.7%
TOTAL		876	596	91	189	687	189
		100%	100%	100%	100%	100%	100%
Percentage			64.4%	11.0%	121.6%	78.4%	21.6%
Chi-sqaure p-value			----------(0.2693)---------			-----(0.1928)------	

Classification:

Food categories: 1 - no food and/or drink consumed at beach.
2 - food and/or drink brought from home consumed at beach.
3 - food and/or drink bought at beach consumed at beach.
4 - food and/or drink brought from home, and bought at beach consumed at beach.

Table 5.8 Continued

FACTOR	n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
BEACH 1	8.0%	9.0%	8.3%	4.8%	8.9%	4.8%
2	39.4%	39.3%	36.5%	41.3%	38.9%	41.3%
3	20.7%	21.9%	25.0%	14.8%	22.3%	14.8%
4	29.1%	25.8%	30.2%	39.2%	26.4%	39.2%
5	1.6%	2.2%	0%	0%	2.0%	0%
6	1.3%	1.9%	0%	0%	1.6%	0%
TOTAL	876	596	91	189	687	189
	100%	100%	100%	100%	100%	100%
Percentage		67.4%	11.0	21.6%	78.4%	21.6%
Chi-square p-value		----------(0.0015)---------			-----(0.0004)------	

Classification:

Beach 1 - Boyd C.A. (Conservation Area).
2 - Claireville C.A.
3 - Albion Hills C.A.
4 - Heart Lake C.A.
5 - Kelso C.A.
6 - Professor's Lake.

Table 5.8 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
INTER-VIEWER	1	4.9%	5.8%	0%	4.8%	5.0%	4.8%
	2	0.2%	0%	2.1%	0%	0.3%	0%
	3	6.6%	7.6%	5.2%	4.2%	7.3%	4.2%
	4	11.1%	9.8%	13.5%	13.8	10.4%	13.8
	5	1.8%	2.4%	0%	1.1%	2.0%	1.1%
	6	8.6%	8.8%	0%	12.2%	7.6%	12.2%
	7	15.4%	17.1%	19.8%	7.9%	17.5%	7.9%
	8	9.2%	10.2%	9.4%	5.8%	10.1%	5.8%
	9	10.5%	10.2%	10.4%	11.6%	10.2%	11.6%
	10	0.2%	0.2%	0%	0.5%	0.2%	0.5%
	11	5.7%	5.9%	8.3%	3.7%	6.3%	3.7%
	12	7.1%	8.1%	7.3%	3.7%	8.0%	3.7%
	13	9.3%	8.6%	0%	15.9%	7.4%	15.9%
	14	9.4%	5.3%	24.0%	14.8%	7.9%	14.8%
TOTAL		876 100%	596 100%	91 100%	189 100%	687 100%	189 100%
Percentage			67.4%	11.0%	21.6%	78.4%	21.6%
Chi-square p-value			----------(0.0001)---------			-----(0.0001)------	

Table 5.8 Continued

FACTOR		n	SWIMMERS	WADERS	NOT IN WATER	IN WATER	NOT IN WATER
NEWSBA	1	34.2%	40.5%	25.0%	19.1%	38.3%	19.1%
	2	65.8%	59.5%	75.0%	81.0%	61.7%	81.0%
TOTAL		876	596	96	189	687	189
		100%	100%	100%	100%	100% 824	100%
Percentage			67.4%	11.0	21.6%	78.4%	21.6%
Chi-square p-value				(0.0001)		(0.0001)	
FOR ILL PEOPLE:							
DR:	1	12.9%	10.9%	6.3%	7.7%	4.1%	7.7%
	2	87.1%	89.1%	93.8%	92.3%	96.0%	92.3%
TOTAL		62	55	2	5	57	5
		100%	100%	100%	100%	100%	100%
Percentage			88.8%	3.3%	8.1%	91.9%	8.1%
Chi-square p-value				(0.2392)		(0.6215)	
FOR ILL PEOPLE:							
HOME:	1	4.8%	5.5%	0%	0%	5.3%	0%
	2	95.2%	94.5%	100%	100%	94.7%	100%
TOTAL		62	55	2	5	57	5
		100%	100%	100%	100%	100%	100%
Percentage			88.8%	3.2%	8.1%	91.9%	8.1%
Chi-square p-value				(0.8196)		(0.5990)	

Classification:

If NEWSBA=1, then the person went swimming or into the water within 4 days before, or 3 days after going to the beach.
If NEWSBA=2, then the person did not do either of the above.
If DR=1, then person visited the doctor.
If DR=2, did not visit the doctor.
If HOME=1, then person stayed home.
If HOME=2, then person did not stay at home.

Table 5.8 Continued

SWIMMERS (persons for whom data was not complete):		
Swallowed water:	yes	33.0%
	no	67.0%
	TOTAL	564 100%
Put head under water:	yes	80.4%
	no	19.7%
	TOTAL	558 100%

modelling (n=876, using the new program; Tables 5.7 to 5.8).

The crude symptom rates for the entire study population, the study population used in logistic regression modelling, and the study population eliminated from the logistic regression modelling are presented in Tables 5.9 to 5.12. For the study population used in logistic regression modelling, the crude symptom rate data are presented for all the water exposure categories (Table 5.10), and for head immersion and water ingestion (Table 5.11).

Detailed discussion of these results will focus on the study population utilized in logistic regression modelling because this population is quite comparable to the entire study population. Furthermore, it is this data set which represents the main focus of this investigation. Characteristic and crude symptom rate data and data for the persons eliminated from the logistic regression modelling are presented for completion, and are not utilized further in the analysis.

5.4 Characteristics of the study population used in logistic regression modelling (refer to Tables 5.5 to 5.6).

In the study population (n=8420), swimmers comprised 79.1%, waders 6.8%, and persons who did not enter the water 14.2%, of the population. If swimmers and waders are grouped collectively, then persons who entered the water

Table 5.9 Crude Symptom Rates for Entire Study Population

TYPE OF ILLNESS	n	SWIMMERS (n=7249)	WADERS (n=665)	NOT IN WATER (n=1382)	p-value	SWIMMERS V. NOT IN WATER Relative risk	SWIMMERS V. NOT IN WATER 95% C.L.	WADERS V. NOT IN WATER Relative risk	WADERS V. NOT IN WATER 95% C.L.
Overall illness	624	570	26	28	0.0001	3.88	2.64, 5.70	1.93	1.12, 3.32
	67.1	78.6	39.1	20.3					
Respiratory	254	235	9	10	0.0001	4.48	2.37, 8.46	1.87	0.76, 4.63
	27.3	32.4	13.5	7.2					
Gastrointestinal	172	157	9	6	0.0001	4.99	2.20, 11.30	3.12	1.10, 8.80
	18.5	21.7	13.5	4.3					
Skin	78	69	1	4	0.0060	3.29	1.20,9.03	0.52	0.06,4.66
	8.0	9.5	1.5	2.9					
Eye	80	73	4	3	0.0108	4.64	1.46, 14.74	2.77	0.62, 12.42
	8.6	10.1	6.0	2.2					
Ear	77	71	4	2	0.0058	6.77	1.66, 27.62	4.16	0.76, 22.75
	8.3	9.8	6.0	1.4					
Allergy	40	34	3	3	0.4217	2.16	0.64, 7.04	2.08	0.42, 10.22
	4.3	4.7	4.5	2.2					
Other	125	113	8	4	0.0008	5.39	1.98, 14.62	4.17	1.25, 13.85
	13.4	15.6	12.0	2.9					
(Sunburn)	920	783	59	78	0.0001	1.91	1.51, 2.43	1.57	1.11,2.23
	99.0	108.0	88.7	56.4					

Comments: The chi-square p-value is quoted. An individual with multiple symptoms may be counted in more than one illness category. 95% C.L. (Confidence Limits) are given by the method of Woolf (e.g. Schlessman, 1982). Sunburn is not considered an illness. Symptom rates per 1000 persons are quoted in each category below the number of persons.

Table 5.9 Continued

TYPE OF ILLNESS	n (n=9296)	IN WATER (n=7914)	NOT IN WATER (n=1382)	p-value	Relative Risk	95% C.L.
Overall ill	624	596	28	0.0001	3.72	2.53, 5.45
	67.1	75.3	20.3			
Respiratory	254	244	10	0.0001	4.26	2.26, 8.04
	27.3	30.8	7.2			
Gastrointestinal	172	166	6	0.0001	4.83	2.14, 10.93
	18.5	21.0	4.3			
Skin	78	70	4	0.0216	3.06	1.11, 8.38
	8.0	8.8	2.9			
Eye	80	77	3	0.0050	4.48	1.41, 14.22
	8.6	9.7	2.2			
Ear	77	75	2	0.0024	6.55	1.61, 26.70
	8.3	9.5	1.4			
Allergy	40	37	3	0.1894	2.15	0.66, 7.00
	4.3	4.7	2.2			
Other	125	121	4	0.0002	5.28	1.95, 14.32
	13.4	15.3	2.9			
(Sunburn)	920	842	78	0.0001	1.89	1.48, 2.39

Comments: The chi-square p-value is quoted. An individual with multiple symptoms may be counted in more than one illness category. 95% C.L. (Confidence Limits) are given by the method of Woolf (Schlessman, 1982). Sunburn is not considered an illness. Symptom rates per 1000 persons are quoted in each category below the number of persons.

Table 5.9 Continued

TYPE OF ILLNESS	SWIMMERS V. NOT IN WATER O.R.	SWIMMERS V. NOT IN WATER 95%c.l.	WADERS V. NOT IN WATER O.R.	WADERS V. NOT IN WATER 95%c.l.	IN WATER V. NOT IN WATER OR.	IN WATER V. NOT IN WATER 95%c.l.
Overall ill	4.13	2.81, 6.06	1.97	1.14, 3.38	3.94	2.68, 5.78
Respiratory	4.60	2.44, 8.68	1.88	0.80, 4.42	4.36	2.31, 8.24
Gastrointestinal	5.08	2.24, 11.50	3.15	1.12, 8.88	4.91	2.17, 11.12
Skin	3.31	1.21, 9.09	0.52	0.06, 4.65	3.07	1.12, 8.43
Eye	4.68	1.47, 14.86	2.78	0.62, 12.46	4.52	1.42, 14.33
Ear	6.83	1.67, 27.86	4.18	0.76, 22.85	6.60	1.62, 26.92
Allergy	2.17	0.66, 7.06	2.08	0.42, 10.35	2.16	0.66, 7.01
Other	5.46	2.01, 14.78	4.19	1.26, 13.98	5.35	1.97, 14.49
(Sunburn)	2.02	1.59, 2.57	1.63	1.15, 2.31	1.99	1.57, 2.53

O.R. - Odds Ratio. 95%c.l. - 95% confidence limits.

Table 5.10 Crude Symptom Rates for Study Population used in Logistic Regression Modelling

TYPE OF ILLNESS	n (n=8420)	SWIMMERS (n=6653)	WADERS (n=574)	NOT IN WATER (n=1193)	p-value	SWIMMERS V. NOT IN WATER Relative risk	SWIMMERS V. NOT IN WATER 95% C.L.	WADERS V. NOT IN WATER Relative risk	WADERS V. NOT IN WATER 95% C.L.
Overall illness	558	511	24	23	0.0001	3.98	2.61, 6.08	2.17	1.21, 3.86
	66.3	76.8	41.8	19.3					
Respiratory	232	216	9	7	0.0001	5.53	2.60, 11.78	2.67	0.99, 7.21
	27.6	32.5	15.7	5.0					
Gastrointestinal	159	144	9	6	0.0004	4.30	1.90,9.76	3.12	1.10, 8.80
	18.9	21.6	15.7	5.0					
Skin	60	56	1	3	0.0235	3.35	1.05, 10.71	0.69	0.07,6.68
	7.1	8.4	1.7	2.5					
Eye	67	61	3	3	0.0438	3.65	1.14, 11.64	2.08	0.42, 10.33
	8.0	9.2	5.2	2.5					
Ear	69	64	3	2	0.0141	5.74	1.40, 23.47	3.12	0.52, 18.71
	8.2	9.6	5.2	1.7					
Allergy	36	31	3	2	0.3254	2.78	0.66, 11.63	3.12	0.52, 18.71
	4.3	4.7	5.2	1.7					
Other	111	99	8	4	0.0056	4.44	1.63, 12.08	4.16	1.25, 13.86
	13.2	14.9	13.9	3.4					
(Sunburn)	775	664	43	68	0.0001	1.75	1.35, 2.27	1.31	1.07, 1.62
	92.0	99.8	74.9	57.0					

Comments: The chi-square p-value is quoted. An individual with multiple symptoms may be counted in more than one illness category. 95% C.L. (Confidence Limits) are given by the method of Woolf (Schlessman, 1982). Sunburn is not considered an illness. Symptom rates per 1000 persons are quoted in each category below the number of persons.

Table 5.10 Continued

TYPE OF ILLNESS	n (n=8420)	IN WATER (n=7227)	NOT IN WATER (n=1193)	p-value	Relative Risk	95% C.L.
Overall ill	558	535	23	0.0001	3.84	2.52, 5.86
	66.3	74.0	19.3			
Respiratory	232	225	7	0.0001	5.31	2.49, 11.29
	27.6	31.1	5.0			
Gastrointestinal	159	153	6	0.0001	4.21	1.86, 9.54
	18.9	21.2	5.0			
Skin	60	57	3	0.0410	3.14	0.98, 10.03
	7.1	7.9	2.5			
Eye	67	64	3	0.0224	3.52	1.10, 9.75
	8.0	8.9	2.5			
Ear	69	67	2	0.0070	5.53	1.35, 22.60
	8.2	9.3	1.7			
Allergy	36	34	2	0.1375	2.81	0.67, 11.70
	4.3	4.7	1.7			
Other	111	107	4	0.0013	4.42	1.62, 12.00
	13.2	14.8	3.4			
(Sunburn)	775	707	68	0.0001	1.72	1.33, 2.22
	9.2	97.8	57.0			

Comments: The chi-square p-value is quoted. An individual with multiple symptoms may be counted in more than one illness category. 95% C.L. (Confidence Limits) are given by the method of Woolf (e.g. Schlessman, 1982). Sunburn is not considered an illness. Symptom rates per 1000 persons are quoted in each category below the number of persons.

Table 5.10 Continued

TYPE OF ILLNESS	SWIMMERS V. NOT IN WATER		WADERS V. NOT IN WATER		IN WATER V. NOT IN WATER	
	O.R.	95%c.1.	O.R.	95%c.1.	O.R.	95%c.1.
Overall ill	4.23	2.77, 6.46	2.22	1.24, 3.97	4.07	2.67, 6.19
Respiratory	5.69	2.67, 12.10	2.70	1.00, 7.28	5.44	2.56, 11.58
Gastrointestinal	4.38	1.93, 9.93	3.15	1.12, 8.90	4.28	1.89, 9.70
Skin	3.37	1.05, 10.77	0.69	0.07, 6.67	3.15	0.99, 10.09
Eye	3.67	1.15, 11.72	2.08	0.42, 10.36	3.54	1.11, 11.30
Ear	5.78	1.41, 23.66	3.13	0.52, 18.78	5.57	1.36, 22.78
Allergy	2.79	0.67, 11.66	3.11	0.52, 18.68	2.81	0.68, 11.73
Other	4.49	1.65, 12.23	4.20	1.26, 14.01	4.47	1.64, 12.14
(Sunburn)	1.83	1.42, 2.37	1.34	1.09, 1.65	1.79	1.39, 2.32

Table 5.11 Crude Sympton Rates for Swimmers used in Logistic Regression Modelling

TYPE OF ILLNESS	n (n=6653)	HEAD UNDER (n=5528)	HEAD OUT (n=1125)	p-value	SWALLOWED WATER (n=1692)	DID NOT SWALLOW WATER (n=4961)	p-value
Overall ill	511	437	74	0.1275	208	303	0.0001
	76.8	79.1	65.8		122.9	61.1	
Respiratory	216	180	36	0.9228	89	127	0.0001
	32.5	32.6	32.0		52.6	25.6	
Gastrointestinal	144	125	19	0.2292	72	72	0.0001
	21.6	22.6	16.9		42.6	14.5	
Skin	56	41	15	0.0477	22	34	0.0168
	8.4	7.4	13.3		13.0	6.9	
Eye	61	55	6	0.1387	23	38	0.0270
	9.2	9.9	5.3		13.6	7.7	
Ear	64	60	4	0.0223	25	39	0.0119
	9.6	10.9	3.6		14.8	7.9	
Allergy	31	25	6	0.7158	10	21	0.3817
	4.7	4.5	5.3		5.9	4.2	
Other	99	78	21	0.2499	45	54	0.0001
	14.9	14.1	18.7		26.6	10.9	
(Sunburn)	664	534	130	0.0532	193	471	0.0234
	99.8	96.6	115.6		114.3	94.9	

Comments: chi-square p-value is quoted. An individual with multiplt symptoms may appear in more than one category.

Table 5.12 Crude Symptom Rates for Persons Eliminated from Logistic Regression Models

Type of Illness	n	SWIMMERS	WADERS	NOT IN WATER	p-value
n	n=876	n=596	n=91	n=189	
Overall illness	70.9	93.2	20.8	26.5	0.0010
Respiratory	24.0	30.5	0	15.9	0.1380(a)
Gastrointestinal	14.9	22.0	0	0	0.0413(a)
Skin	16.0	22.0	0	5.3	0.1164(a)
Eye	14.9	20.3	10.4	0	0.1230(a)
Ear	9.1	11.9	10.4	0	0.3257(a)
Allergy	4.6	5.1	0	5.3	0.7801(a)
Other	11.4	16.9	0	0	0.0869(a)
(Sunburn)	161.1	194.9	166.7	52.9	0.0001

Type of Illness	n	IN WATER	NOT IN WATER	p-value
n	n=876	n=687	n=189	
Overall illness	70.9	63.1	26.5	0.0072
Respiratory	24.0	26.2	15.9	0.4097(a), 0.5925(b)
Gastrointestinal	14.9	19.0	0	0.5925(a), 0.0826(b)
Skin	16.0	19.0	5.3	0.1851(a), 0.3237(b)
Eye	14.9	19.0	0	0.0566(a), 0.0826(b)
Ear	9.1	11.7	0	0.1358(a), 0.2127(b)
Allergy	4.6	4.4	5.3	0.8685(a), 1.0000(b)
Other	11.4	14.6	0	0.0950(a), 0.1301(b)
(Sunburn)	161.1	191.0	52.9	0.0001, <0.0001(b)

Comments:
(a) More tha 20% of the cells have expected counts of under 5, so this chi-square p-value may not be a valid test. (b) p-value for Fisher's exact two-tailed test where 20% of the cells have expected counts of 5 and under. An individual with multiple symptoms may be included in more than one illness category.

made up 85.8% of the study population. Although investigators would prefer a larger control population of persons who did not enter the water, the survey was initiated in the belief that there would be a large population of nonswimmers.

In the study population (n=8420), the four age groups (Table 5.5) which contained the highest percentages of participants were found in the following young age groups: 1) the 20 to under 25 age group (13.8%), 2) the 5 to under 10 age group (12.7%), 3) the 15 to under 20 age group (11.7%), and 4) the 10 to under 15 age group (11.6%). For swimmers (n=6653) these four age groups were the same (i.e. the 5 to under 10 (15.0%), 20 to under 25 (14.0%), 10 to under 15 (13.7%), and 15 to under 20 (12.8%) age groups). For waders (n=574), the following four age groups contained the highest percentages of waders: 1) the 30 to under 35 (17.6%), 25 to under 30 (15.0%), 20 to under 25 (12.8%), and 0 to under 5 (10.2%) age groups. For persons who did not go into the water (n=1193), the four groups which contained the highest percentages of participants, contained more older participants than that found in the study population, and wader or swimmer populations (i.e.: 35 to under 40 -14.2%, 30 to under 35 - 14.1%, 20 to under 25 -13.9%, and 25 to under 30 -12.1%). For swimmers and waders combined (i.e.: persons who entered the water, n=7227), the four age groups which contained the highest percentages of participants were the same as those determined for the study population and swimmers (i.e.: 5

to under 10 - 14.4%, 20 to under 25 - 13.1%, 10 to under 15 - 12.8%, and 15 to under 20 - 12.2%). It was apparent for the study population, swimmers, waders, persons who entered the water, and persons who did not enter the water, that few participants were found in the older age groups. These results are depicted graphically in Figure 5.1.

When swimmers, waders, and persons who did not enter the water were tested to ascertain whether water exposure was independent of age group, a statistically significant association was observed (chi-square p-value = 0.0001), and the same held true when persons who entered the water and persons who did not enter the water (chi-square p-value = 0.0001) were tested.

When the study population was categorized by sex (Table 5.6), slightly more of the population was found to be female in gender (53.6%) compared to male (46.4%). Figure 5.2 illustrates that this relationship also held true for the swimmers (52.2% female and 49.8% male), waders (61.5% female and 38.5% male), persons who did not enter the water (57.8% female and 42.3% male), and persons who entered the water (52.9% female and 47.1% male). The difference in percentages was largest for the wader category.

When swimmers, waders, and persons who did not enter the water, and persons who entered the water versus those who did not, were tested to ascertain whether water exposure was independent of sex, statistically significant associations at the 0.0001 and 0.0019 levels, respectively,

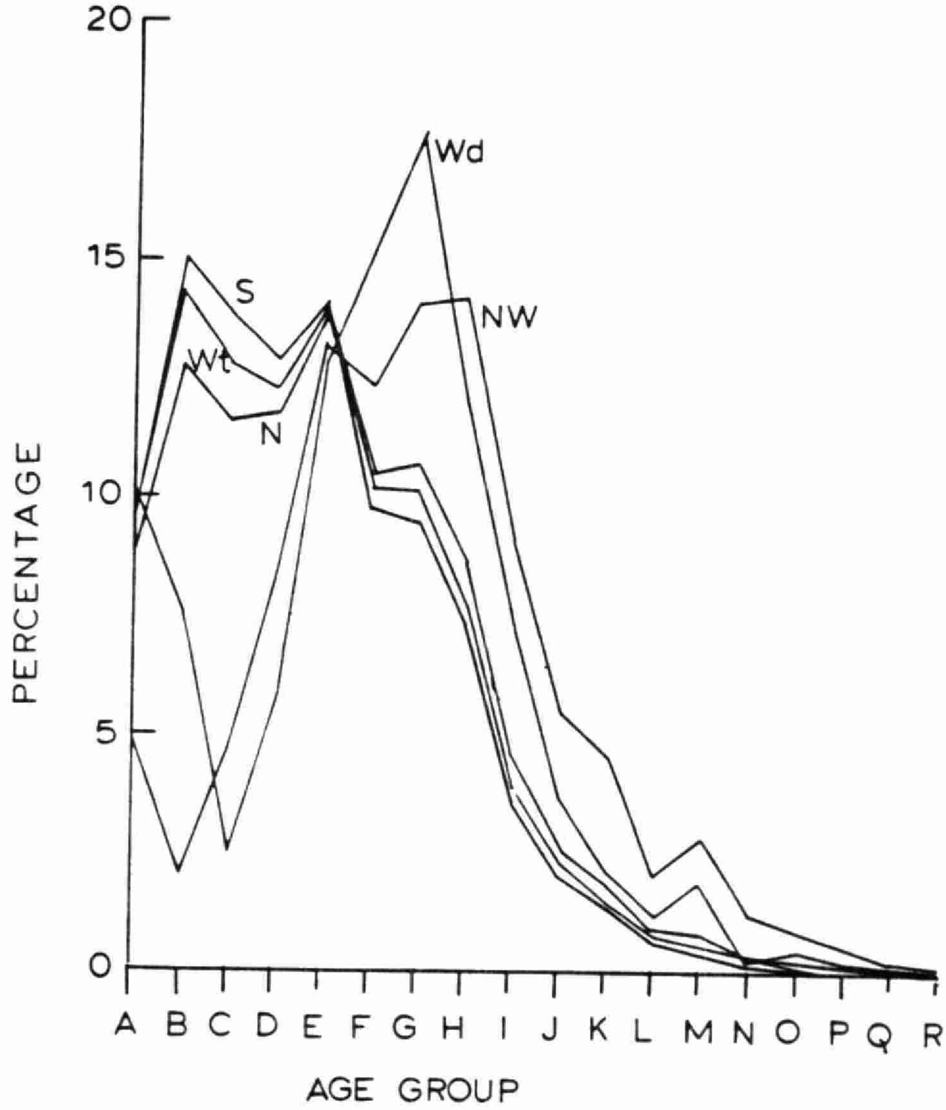

Figure 5.1 The Age Distribution of the Study Population and Various Subgroups

were found.

The large concentration of inhabitants, and thus beach-goers, of Italian descent nearby the Boyd and Claireville areas introduced a possible confounding variable to modelling. For this reason, it was necessary to ascertain whether the subjects were of Italian descent. Direct questionning of the subjects was deemed too offensive, and interviewers were requested to evaluate this based on the subject's last name. Admittedly, this method was rather crude and may not be very accurate. The majority of the study population was found not to be of Italian descent (70.8% versus 29.2%). The same was true for swimmers (71.8% versus 28.2%), waders (73.9% versus 28.1%), persons who did not enter the water (64.3% versus 35.7%), and persons who entered the water (71.9% versus 28.1% - Figure 5.2). When swimmers, waders and persons who did not enter the water, as well as persons who entered the water versus those who did not, were tested to ascertain whether water exposure was independent of Italian descent, statistically significant associations (chi-square p-value=0.0001) were found.

The percentage of contact persons was much smaller than the number of noncontact persons in: the study population (23.7% versus 76.3%), the swimmer population (21.9% versus 76.3%), the wader population (35.9% versus 64.2%), the population of persons who did not enter the water (28.4% versus 71.6%), and the population of persons who entered the water (23.0% versus 77.1% - Figure 5.3).

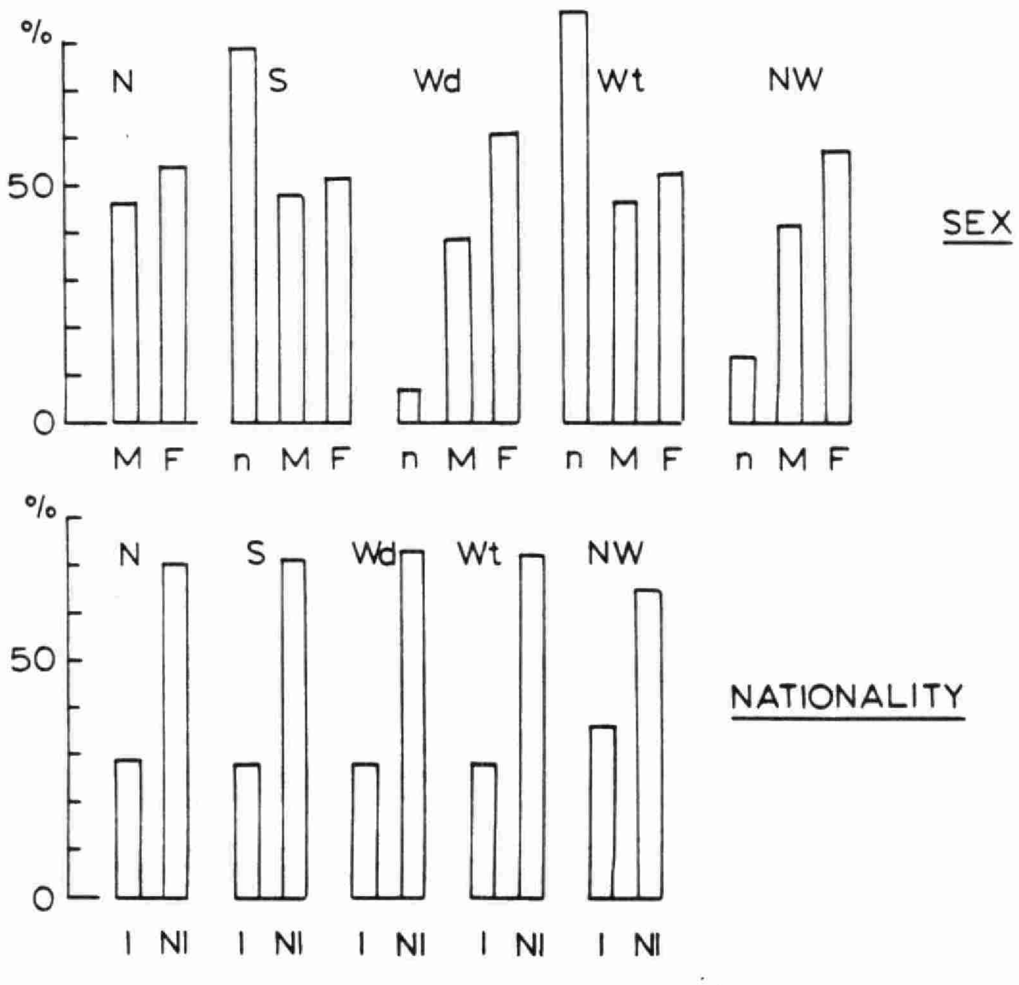

Figure 5.2 The Sex and Italian Race Distributions of the Study Population and its Subgroups

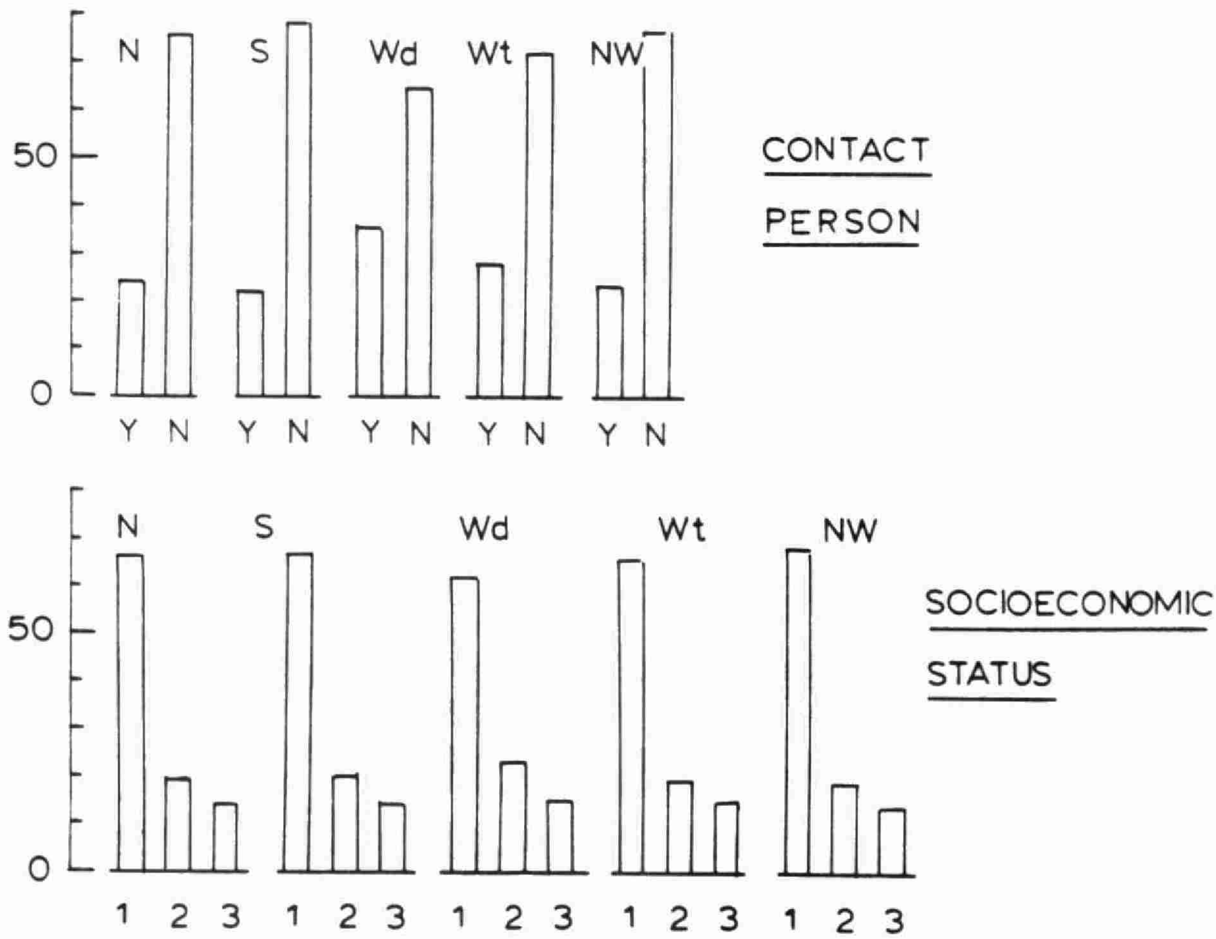

Figure 5.3 The Contact Person and Socioeconomic Status Distribution of the Study Population

When swimmers, waders, and persons who did not enter the water, and persons who entered the water versus those who did not, were tested to ascertain whether water exposure was independent of contact person status, statistically significant associations (chi-square p-value=0.0001) were found for both.

Three categories of socioeconomic status (SES) were created (based on Cabelli _et_ _al_. (1979). Cabelli _et_ _al_. (op cit) divided the number of persons in the household by the number of rooms in the household, and designated three categories. The approach adopted here was to exclude kitchens and bathrooms, because it was felt that they were not living quarters.

The three categories utilized for the person-to-room ratios were:

1. Less than or equal to 0.9 (SES=L1 - high SES).

2. Greater than 0.9 but less than or equal to 1.3 (SES=L2 - moderate SES).

3. Greater than 1.3 (SES=L3 - low SES).

For the study population, the highest percentage of subjects were of high SES (66.6%), followed by the middle SES category (19.8), and finally by the low SES category (13.7%). The same pattern was found for swimmers (66.7%, 19.7%, and 13.7%, respectively), waders (62.9%, 23.0%, and 14.1%, respectively), persons who did not enter the water (67.9%, 18.7%, and 13.4%, respectively), and persons who entered the water (66.4%, 19.9%, and 13.7%, respectively). These results are displayed in Figure 5.3. When swimmers,

waders, and persons who did not go in the water, were tested to determine whether water exposure was independent of SES category, a statistically significant association (chi-square p-value=0.2508) was not found. Likewise, no statistically significant association was found when persons who went into the water and persons who did not go into the water were tested in the same manner (chi-square p-value=0.5457).

Food or drink consumption was divided into four categories:

1) No food and/or drink was consumed at the beach.

2) Food and/or drink brought from home was consumed at the beach.

3) Food and/or drink bought at the beach was consumed at the beach.

4) Food and/or drink brought from home, and bought at the beach were consumed at the beach.

In the study population, most people belonged to the second category (51.0%), followed by the fourth (26.9%), third (14.8%), and first (7.4%) categories. The order was the same for swimmers (48.2%, 28.4%, 15.8%, and 7.6%, respectively), waders (54.8%, 26.4%, 14.2%, and 4.6%, respectively), persons who did not enter the water (64.8%, 18.4%, 9.5%, and 7.3%, respectively), and persons who entered the water (48.7%, 28.3%, 15.%, and 7.4%, respectively). When swimmers, waders and people who did not go in the water, and people who went in the water versus people who did not enter the water were tested to ascertain

whether water exposure was independent of food consumption category, statistically significant associations (chi-square p-value=0.0001) were found for both.

The highest percentage of study population subjects were interviewed in July (64.5%), followed by August (26.9%), and June (8.9%). Interviewing commenced only during the last weekend of June. The pattern was the same for swimmers (62.9%, 28.1%, and 8.9%, respectively), waders (57.5%, 33.0%, and 9.5%, respectively), and persons who did not enter the water (76.8%, 14.9%, and 8.3%, respectively). When swimmers, waders, and persons who did not enter the water, and persons who entered the water versus those who did not enter the water, were tested to ascertain whether water exposure was independent of the month of the study, statistically significant associations were found for both tests (chi-square p-value=0.0001).

The study was conducted at six beaches, and the beaches were designated as follows:

1. Boyd C.A. - Beach 1
2. Claireville C.A. - Beach 2.
3. Albion Hills C.A. - Beach 3.
4. Heart Lake C.A. - Beach 4.
5. Kelso C.A. - Beach 5.
6. Professor's Lake - Beach 6.

For the study population, the percentage of subjects interviewed at each beach decreased in the order: Beach 3 > (greater than) Beach 4 > Beach 2 > Beach 6 > Beach 1 > Beach 5. For swimmers the order was: Beach 3 > Beach 6 >

Beach 2 > Beach 4 > Beach 1 > Beach 5. For waders the order was: Beach 3 > Beach 4 > Beach 6 > Beach 2 > Beach 1 > Beach 5. The order for persons who did not go into the water was Beach 4 > Beach 3 > Beach 2 > Beach 1 > Beach 5 > Beach 6. For persons who entered the water, the order was: Beach 4 > Beach 3 > Beach 2 > Beach 1 > Beach 5 > Beach 6 (Table 5.6). When swimmers, waders, and persons who did not enter the water, and persons who entered the water versus those who did not enter the water, were tested to ascertain whether water exposure was independent of beach location, statistically significant associations were found for both (chi-square p-value=0.0001).

The distribution of the percentage of interviews conducted by each interviewer is given in Table 5.6. When a test was performed to evaluate whether water exposure was independent of the interviewer (see above), statistically significant associations were found (chi square p-value=0.0001).

The possibility that exposure to water at different locations or the same location up to four days before, or three days after, the first interview required investigation. Of the study population, 64.0% did not go in the water four days before or three days after the beach interview, whereas 36.0% did go in the water during this period. For swimmers, the respective percentages were 59.1% and 40.9%, respectively. For waders the values were 76.6% and 23.4%, respectively. For persons who did not enter the water, these values were 85.3% and 14.7%. For people who

entered the water, the respective percentages were 60.5% and 39.5%. Tests were performed to ascertain whether water exposure was independent of swimming history and statistically significant associations (chi-square p-value=0.0001) were found for both.

Of the persons who became ill in the study population, 88.4% did not visit the doctor, whereas 11.6% did visit the doctor. A similarly large proportion of the ill persons did not visit the doctor in both the populations of swimmers (87.9% versus 12.1%), waders (95.8% versus 4.2%), persons who did not enter the water (91.3% versus 8.7%), and persons who entered the water (88.2% versus 11.8%). Testing to determine whether water exposure was independent of whether the doctor was visited, or not, did not reveal statistically significant associations (chi-square p-value=0.4500 for swimmers, waders, and persons who did not enter the water, and 0.652, for persons who entered the water versus those who did not, respectively.

For persons who became ill out of the study population , 93.2% did not stay at home, whereas 6.8% did stay at home. A similar pattern emerged in the case of the waders (100% versus 0%), swimmers (93.0% versus 7.0%), persons who did not enter the water (91.3% versus 8.7%), and persons who entered the water (93.3% versus 6.7% - Table 5.6). No statistically siginificant associations were found when testing of whether water exposure was independent of whether the person stayed at home or not (chi-square p-values were 0.3794 and 0.7139 for swimmers, waders, and

persons who did not enter the water, and for persons who entered the water versus persons who did not enter the water) was undertaken.

It was found that 74.6% of the swimmers admitted swallowing water, whereas 25.4% of them did not admit to swallowing water. In addition, 83.1% of the swimmers admitted to immersing their head under water, in contrast to 16.9% who did not admit that.

5.5 Crude Symptom rates for the study population used in logistic regression modelling

The crude symptom rates for the study population (n=8420) appear in Table 5.10. Sunburn was not considered to be an illness because it was believed that it would result in an overestimate of the illness detected. Rather, a more conservative approach was adopted. Overall illness included all reported symptoms. Respiratory illness (or symptoms) was defined as: sore throat, a cold or cough, or a runny or stuffed nose (an individual with multiple symptoms in one illness category is counted only once in that illness category, but may appear in more than one category). Gastrointestinal illness was defined as: stomachache or nausea, diarrhea, or vomiting. Skin problems consisted of boils or a skin rash. Eye illness was defined as: styes, red, itchy, or watery eyes. Earache or runny ears constituted ear illness. Allergic itch, welts or sneezing comprised allergic illness. Other ailments were

composed of fever, because it is a nonspecific symptom potentially associated with several categories of illness, and any other reported symptoms.

For the study population, respiratory symptoms constituted the highest symptom rate observed (27.6 per 1000 persons), followed by: gastrointestinal (18.9 per 1000), other (13.2 per 1000), ear (8.2 per 1000), eye (8.0 per 1000), skin (7.1 per 1000), and allergic symptoms (4.3 per 1000). For overall illness, the study population displayed a crude symptom rate of 66.3 per 1000 persons.

For swimmers, respiratory symptoms also comprised the highest crude symptom rate (32.5 per 1000), followed by: gastrointestinal (21.6 per 1000), ear (19.6 per 1000), eye (9.2 per 1000), skin (8.4 per 1000), and allergic symptoms (4.7 per 1000). An overall illness crude symptom rate of 76.8 per 1000 swimmers was detected.

Respiratory and gastrointestinal symptoms in waders also represented the highest crude symptom rates observed (15.7 per 1000 waders, for both ailments), followed by: other symptoms (13.9 per 1000 waders), eye, ear, and allergic symptoms (5.2 per 1000 waders), and skin symptoms (1.7 per 1000 waders). An overall crude symptom rate of 41.8 per 1000 waders was observed.

For persons who did not enter the water, respiratory and gastrointestinal symptoms figured predominantly (5.0 per 1000 persons who did not enter the water), followed by: other symptoms (3.4 per 1000 persons who did not enter the water), eye and skin symptoms (2.5 per 1000 persons who did

not enter the water), and ear and allergic symptoms (1.7 per 1000 persons who did not enter the water). An overall crude symptom rate of 19.3 per 1000 persons who did not enter the water was detected.

For persons who entered the water, respiratory symptoms figured prominently (31.1 per 1000 persons who entered the water), followed by: gastrointestinal (21.2 per 1000 persons who entered the water), other (14.8 per 1000 persons who entered the water), ear (9.3 per 1000 persons who entered the water), eye (8.9 per 1000 persons who entered the water), skin (7.9 per 1000 persons who entered the water), and allergic symptoms (4.7 per 1000 persons who entered the water). An overall crude symptom rate of 74.0 per 1000 persons who entered the water was observed.

Figure 5.4 displays the differences in crude symptom rates among swimmers, waders, and persons who did not go into the water. There was an interesting general trend of greater morbidity in swimmers, versus waders, versus persons who did not go into the water, in all categories of illness other than skin (where the order was swimmers, persons who did not enter the water, and waders). Significant associations, at the 5% level or better, were detected when water exposure and morbidity outcome were tested for independence (i.e.: using a 3*2 table) for all types of morbidity other than for allergic symptoms (Table 5.10). In fact, the order of significance from most to least was: overall and respiratory symptoms (chi-square p-value=0.0001), gastrointestinal symptoms (chi-square

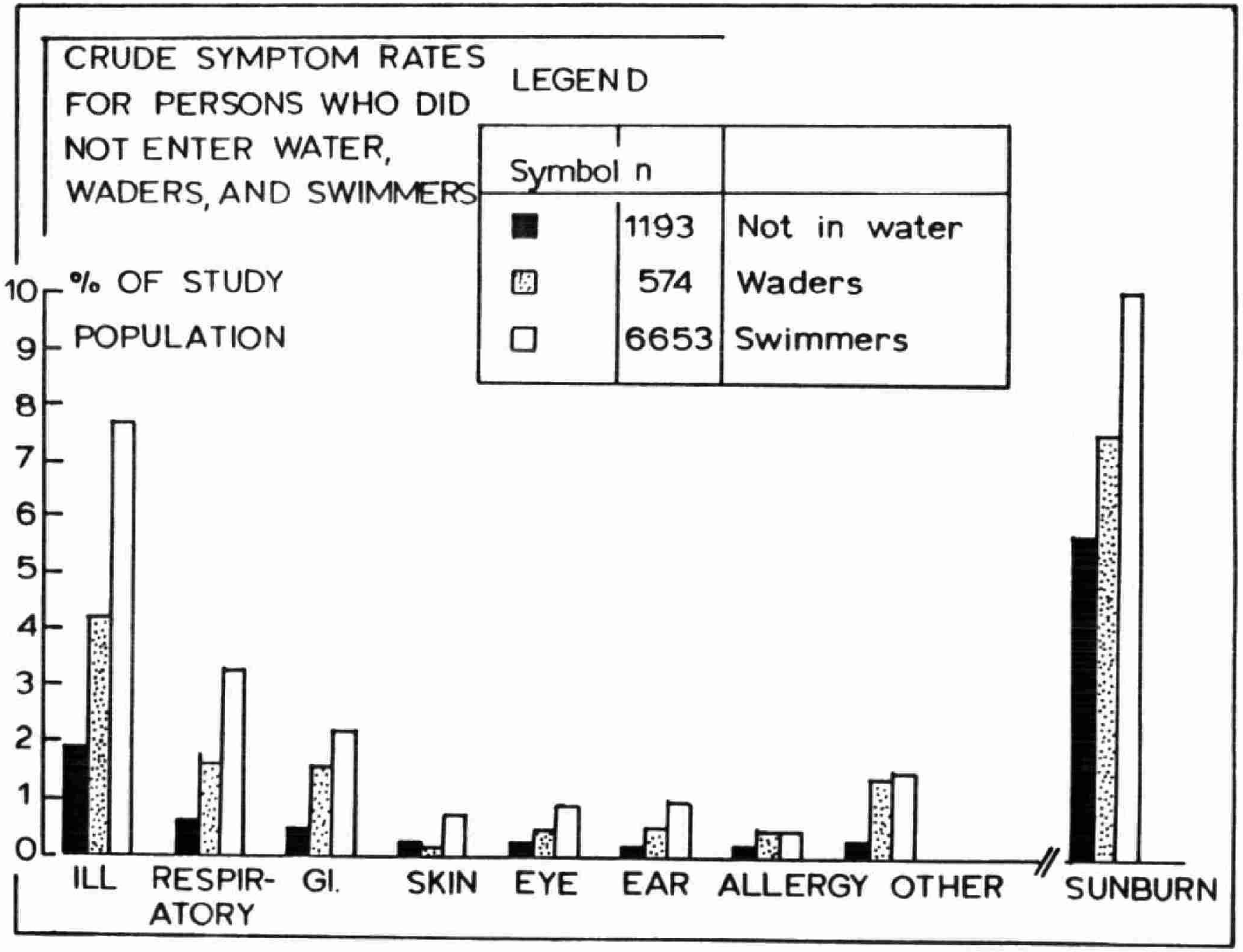

Figure 5.4 Crude Symptom Rates for Swimmers, Waders, and Persons Who Did Not Enter the Water (n=8420)

p-value=0.0004), other symptoms (chi-square p-value=0.0056), ear symptoms (chi-square p-value=0.0141), skin symptoms (chi-square p-value=0.0235), eye symptoms (chi-square p-value=0.0438), and allergic symptoms (chi-square p-value=0.3254).

Both relative risks and odds ratios were calculated for the data in Table 5.10. Relative risks are obtained directly and exactly in prospective studies (Schlessman, 1982). However, the odds ratio represents an estimation of relative risk (Schlessman, 1982). Odds ratios were provided in addition to relative risks because only they are available for the multivariate logistic regression models utilized (Schlesselman, 1982). It was intriguing that for swimmers versus persons who did not enter the water the relative risks and odds ratios for illnesses were all greater than 2.0. The same was true for waders, except for the skin category. Although these represent crude data only, it will be interesting to see if these elevated risks were reflected in the multivariate analyses, such that swimming and wading might represent important sources of risk elevation.

One can also present the data in Table 5.10 by two exposure categories (persons who did not enter the water versus those who did). For persons who entered the water, respiratory symptoms constituted the highest symptom rate observed (31.1 per 1000 persons who entered the water), followed by: gastrointestinal symptoms (21.2 per 1000 persons who entered the water), other symptoms (14.8 per

1000 persons who entered the water), ear symptoms (9.3 per 1000 persons who entered the water), eye symptoms (8.9 per 1000 persons who entered the water), skin symptoms (7.9 per 1000 persons who entered the water), and allergic symptoms (4.7 per 1000 persons who entered the water). For overall illness, the persons who went into the water displayed a crude symptom rate of 74.0 per 1000 persons who went into the water. Clearly, there was an interesting general trend to greater morbidity in persons who entered the water versus those who did not enter the water. Significant associations, at the 5% level or better, emerged when water exposure and morbidity outcome were tested for independence (i.e.: using a 2*2 table) for all types of morbidity other than for allergic symptoms. Specifically, the order of significance from most to least was: overall, respiratory, and gastrointestinal symptoms (chi-square p-value=0.0001), other symptoms (chi-square p-value=0.0013), ear symptoms (chi-square p-values=0.0070), eye symptoms (chi-square p-value=0.0244), skin symptoms (chi-square p-value=0.0410), and allergic symptoms (chi-square p-value=0.1375).

Relative risks and odds ratios were calculated for the data by the two categories of exposure. For persons who entered the water, in contrast to those who did not, relative risks and odds ratios were all greater than 2.0. These crude trends require multivariate analysis in order to ascertain if exposure to the water represents an important factor which elevates the risk of becoming ill.

It is also important to note that the initial

interview data were examined in conjunction with the follow-up data, in order to ensure that the illness reported had not been manifested prior to going to the beach.

Crude symptom rate data is presented in Table 5.11 for head immersion and water ingestion in swimmers. Swimmers who immersed their head had more elevated crude symptom rates than swimmers who did not immerse their head for overall illness (79.1 versus 65.8 per 1000 swimmers, respectively), ear symptoms (10.9 versus 3.6 per 1000 swimmers, respectively), gastrointestinal symptoms (22.6 versus 16.9 per 1000 swimmers respectively), eye symptoms (9.9 versus 5.3 per 1000 swimmers, respectively), and respiratory symptoms (32.6 versus 22.0 per 1000 swimmers, respectively). The reverse was true for skin symptoms (7.4 versus 13.3 per 1000 swimmers, respectively), other symptoms (14.1 versus 18.7 per 1000 swimmers, respectively), and allergic symptoms (4.5 versus 5.3 per 1000 swimmers, respectively). Significant associations, at the 5% level or better, were detected when persons who immersed their head in contrast to those who did not were tested for independence against whether they had ear symptoms, or not (chi-square p-value=0.0223), or skin problems, or not (chi-square p-value=0.0477).

Swimmers who swallowed water displayed elevated crude symptom rates versus those who did not swallow water for all categories of morbidity whose order of magnitude difference from highest to lowest was: overall symptoms

(122.9 versus 61.1 per 1000 swimmers, respectively), gastrointestinal symptoms (42.6 versus 14.5 per 1000 swimmers, respectively), respiratory symptoms (52.6 versus 25.6 per 1000 swimmers, respectively), other symptoms (114.1 versus 94.9 per 1000 swimmers, respectively), ear symptoms (14.8 versus 7.9 per 1000 swimmers, respectively), skin symptoms (13.0 versus 6.9 per 1000 swimmers, respectively), eye symptoms (13.6 versus 7.7 per 1000 swimmers, respectively), and allergic symptoms (5.9 versus 4.2 per 1000 swimmers, respectively). Significant associations,at the 5% level or better, emerged when persons who swallowed water in contrast to those who did not were tested for independence against the overall, respiratory, gastrointestinal, and other symptom (chi-square p-value=0.0001) outcomes, ear symptom (chi-square p-value=0.0119) outcomes, skin symptom (chi-square p-value=0.0168) outcomes, eye symptom (chi-square p-value=0.0270) outcomes, and allergic symptom (chi-square p-value=0.3817) outcomes.

5.6 Summarizing comments

A large number of subjects were included in this study. Preliminary analysis of the crude data signalled that some important associations emerged between water exposure and various factors. Clearly, multivariate analysis is necessary to ascretain whether: 1) the general trend of greater morbidity in swimmers followed by waders

and persons who did not enter the water, respectively, is upheld, and 2) the relative risk (and odds ratio) data are indicative of the actual risks incurred.

One can refer to the Appendix (Table 9.4 to 9.8) for a listing of the relevant crude epidemiological data in this study (for n=8420 people).

CHAPTER 6

LINEAR REGRESSION MODELLING

6.1 Reasons for presenting linear regression models

Cabelli (1980; 1981; 1983) and his colleagues (1982; Dufour, 1982; Dufour, 1985), without doubt, represent the pioneers of predictive regression modelling in the field of microbial induced swimming-related illness. Their efforts have added a whole new dimension and sophistication to the field, although they have only utilized simple linear regression modelling techniques. As a result, officials from the Ontario Ministry of the Environment suggested that the data presented in this thesis should be initially evaluated in this fashion. At this point, the author emphasizes that such models may be unrealistic, and should be treated with extreme caution, since they may reflect the confounding effects of variables external to the models, and could therefore be biased. Thus, the present chapter is intended to be purely exploratory in nature.

6.2 Modelling population and background effects

One can present results for simple linear regression modelling of swimming-related illness in a variety of ways. In all cases, the models involve the determination of the relationship of some function of illness (y-axis) to some function of the bacterial count (x-axis). Some

investigators utilize proportions (ill/total), while others utilize probabilities (ill/not ill). When the illness rates are small (i.e. 5 to 10%), there is little difference between the two methods (Dr. D. Andrews, personal communication). Cabelli and his associates (op. cit.) utilized proportions, and removed the miscellaneous background illness effects by sutraction, as follows:

y=(ill swimmers/total swimmers)
 - (ill nonswimmers/total nonswimmers).

For the purpose of the present study, it was felt that a preferable way of presenting the illness data was in the form of a probability, as follows:

y=(ill swimmers/ not ill swimmers).

No background control was included in the model, that is, subtraction of symptom rates of people who did not enter the water (inclusive or not inclusive of waders). It was decided to concentrate on swimmers only, because:

1. The number of persons who did not enter the water represented only a small subset of the total population interviewed (1382 persons did not enter the water, and there were 665 waders, whereas the number of swimmers was 7249). Clearly the use of an unrepresentative control population symptom rate could bias the results.

2. The waders could be included with either the

swimmers or the persons who did not go into the water, and were difficult to assess in terms of exposure to the water because only a small portion of the body was exposed, and thus may not bear the full impact of a particular bacterial density.

3. Numerous potentially confounding variables (e.g.: age, contact person, and interviewer) made the use of background control populations complicated. For example, Figure 5.1 shows that the age distribution for the swimmers compared to the persons who did not enter the water and waders was quite distinctive. The population of persons who did not go into the water included a smaaller percentage of young people, and a larger percentage of old people than the swimming or wading populations.

4. Illness rates often tend to be considerably higher in very young and very old people, and thus direct subtraction of a background population which does not take this into account could prove misleading.

Cabelli and his co-workers (op. cit.) define a swimmer in a different way when compared to this study. Cabelli and his colleagues (1982) define a swimmer as a person who has immersed their head in water (i.e.: "complete exposure of the head to the water" - Cabelli, 1982). All other persons were designated by Cabelli (1982) as nonswimmers. In this study, a wader was defined as a person who entered the water to knee-depth at maximum, and a swimmer was defined as any person who was exposed to the water beyond knee-depth. It is our opinion that head immersion and

associated water ingestion do not represent the sole routes of body entry by microbes derived from recreational waters. Furthermore, reporting by the contact person tends to be poor for the subject of head immersion. A list of other differences in microbial methodologies and definitions of illness categories appears in Table 6.1

6.3 Data used for unadjusted regression modelling

In Table 6.2, the relevant data employed for simple linear regression modelling are presented.

6.4 Correlations between bacterial densities and reported symptoms

A correlation coefficient procedure in SAS (PROC CORR, SAS, 1982b) was employed. The values are quoted in Table 6.3 for the relationship between the $\log_{10}$ of te geometric mean count and the probability of illness (i.e.: (p/1-p) e.g.: gastrointestinal, skin, and overall illness) by beach, month and date. Gastrointestinal (GI) ailments were of particular interest because of their predominance in the studies performed by Cabelli and his colleagues (1982). Overall illness and skin symptoms were also investigated (Brown, 1983).

Colton (1974) indicated that correlations from 0 to 0.25 reveal little to no relationship, those from 0.25 to 0.50 display a fair degree of relationship, and those

Table 6.1 Differences between These Studies and Those of Cabelli *et al.* (1980, 1982).

Cabelli *et al.* (1980, 1982)	This study
1. ILLNESS CATEGORIES:	
GI - vomiting - diarrhea - stomachache - nausea	GI - vomiting - diarrhea - stomachache or nausea
RESPIRATORY: - sore throat - bad cough - chest cold - runny or stuffy nose - earache or runny ears - sneezing, wheezing, tightness in chest	RESPIRATORY: - sore throat - cough or cold - runny or stuffed nose
	EAR: - earache, or runny ears
	ALLERGY: - allergic itch, welts, or sneezing
OTHER: - fever (over 37.78°C) - headache (more than a few hours) - backache - skin rash, itchy skin, welts	OTHER: - fever (over 98.6°F or 36.5°C) - any other symptom
DISABLING: - home because of symptoms - in bed because of symptoms - medical help because of symptoms	- home because of symptoms - doctor seen due to symptoms
	EYE: - styes or red, itchy or watery eyes
	SKIN: - boils - skin rash
2. BACTERIOLOGICAL MEDIA:	
fecal coliforms - mC medium	fecal coliforms - mTEC medium
E. coli - mTEC after 1974, mC prior to that.	*E. coli* - mTEC medium
enterococci - mE medium	enterococci - mE medium

Table 6.2 Data Utilized in Unadjusted Regression Modelling

BEACH	MONTH	DATE	Log10(bacterial count)								Number of ill swimmers			No. not ill swimmers					Overall Ill/Not ill(swimmers)		
			St	Het	Ec	Fec	Str	Ent	Pam	Pat	GI	SKIN	ILL	GI	SKIN	ILL	Swimmers	People	GI	SKIN	ILL
1	6	25	n.a.	7.12	2.76	2.78	1.92	0.69	0.30	0.54	0	3	4	47	44	43	47	61	0	0.06818	0.09302
1	6	26	2.39	7.45	2.95	3.07	2.30	0	0.95	0.98	0	0	3	57	57	54	57	97	0	0	0.05556
1	7	1	2.36	7.79	3.32	3.36	2.67	2.15	1.07	0.74	3	1	10	207	209	200	210	261	0.01449	0.00478	0.05000
1	7	2	2.48	7.00	2.91	2.96	2.36	2.07	1.43	0.93	0	1	15	262	261	247	262	322	0	0.00383	0.06073
1	7	3	3.13	6.70	3.27	3.36	2.91	2.41	1.62	1.26	4	1	19	302	305	287	306	371	0.01325	0.00328	0.06620
2	6	25	n.a.	7.00	2.72	2.75	2.73	0.60	0.98	1.02	3	4	19	168	167	152	171	270	0.01786	0.02395	0.12500
2	6	26	2.77	6.50	2.64	2.67	2.34	2.00	1.01	0.96	5	0	15	241	246	231	246	285	0.02075	0	0.06494
2	7	1	2.65	6.70	2.62	2.68	1.91	1.69	0.15	0.39	0	0	0	31	31	31	31	40	0	0	0
2	7	2	2.70	6.47	2.53	2.99	2.33	1.74	0.72	0.59	1	0	2	49	50	48	50	67	0.02041	0	0.04167
2	7	3	2.69	6.66	2.75	2.80	2.27	1.93	1.56	1.13	4	2	5	69	71	68	73	94	0.05797	0.02817	0.07353
2	7	9	2.56	6.44	3.01	3.11	2.21	1.37	0.99	0.60	2	0	6	82	84	78	84	133	0.02439	0	0.07692
2	7	10	2.51	6.93	2.48	2.48	2.17	1.56	1.98	1.14	2	4	21	215	213	196	217	287	0.00930	0.01878	0.10714
2	7	16	2.81	6.86	3.13	3.15	2.24	1.82	1.47	0.90	13	7	34	209	215	188	222	256	0.06220	0.03256	0.18085
2	7	17	2.92	6.38	3.27	3.30	2.50	2.26	1.07	1.50	6	7	30	234	233	210	240	314	0.02564	0.03004	0.14286
2	7	24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2	1	3	38	39	37	40	n.a.	0.01078	0.02564	0.08108
3	6	25	n.a.	6.97	1.84	1.88	1.79	0.00	0.24	0.45	3	1	11	81	83	73	84	118	0.03704	0.01205	0.15068
3	6	26	1.91	7.00	2.03	2.04	1.29	0	0	0.39	2	4	12	189	187	179	191	252	0.01058	0.02139	0.06704
3	7	1	1.80	6.75	2.18	2.21	1.86	1.25	0.48	0.24	6	1	16	122	127	112	128	152	0.04918	0.00787	0.14286
3	7	2	1.85	6.90	2.43	2.45	1.83	1.08	0.75	0.35	9	2	24	163	170	148	172	199	0.05522	0.01176	0.16216
3	7	3	2.27	6.20	2.99	3.02	2.09	1.52	0.57	0.72	6	2	21	181	185	166	187	217	0.03315	0.01081	0.12651
3	7	6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0	0	0	2	2	2	2	n.a.	0	0	0

Table 6.2 Continued.

BEACH	MONTH	DATE	Log10(bacterial count)								Number of ill swimmers			No. not ill swimmers			Overall		Ill/Not ill(swimmers)		
			St	Het	Ec	Fec	Str	Ent	Pam	Pat	GI	SKIN	ILL	GI	SKIN	ILL	Swimmers	People	GI	SKIN	ILL
3	7	9	1.78	6.74	7.18	2.20	1.42	0.91	0.15	0	1	0	3	41	42	39	42	59	0.02439	0	0.07692
3	7	10	2.06	7.00	1.90	1.92	1.50	0.78	0.45	0.48	1	2	12	236	235	225	237	284	0.00424	0.00851	0.05333
3	7	16	1.72	6.75	2.29	2.29	1.37	1.30	0.60	0.54	5	1	13	205	209	197	210	223	0.02439	0.00478	0.06599
3	7	17	2.39	6.44	2.22	2.29	2.01	1.30	0	1.22	3	1	19	272	274	256	275	300	0.01103	0.07422	0.00365
3	7	23	1.76	6.85	2.62	2.64	1.82	1.37	0	0.50	0	0	6	112	112	106	112	142	0	0	0.05660
3	7	24	1.67	2.40	2.47	1.64	1.09	0.52	0.30	0	0	0	3	107	107	104	107	180	0	0	0.02885
3	7	30	1.84	6.00	2.80	2.91	2.03	1.71	0.42	0.39	1	0	3	51	52	49	52	78	0.01961	0	0.06122
3	7	31	2.29	6.29	3.06	3.12	2.53	2.28	1.52	1.35	0	0	0	5	5	5	5	6	0	0	0
3	8	1	2.12	6.28	3.12	3.17	2.54	2.00	1.45	1.37	0	0	5	84	84	79	84	127	0	0	0.05952
3	8	6	2.28	6.47	2.91	3.00	1.97	1.95	0.48	0.80	2	0	4	107	109	105	109	126	0.01869	0	0.03810
3	8	7	2.62	6.53	2.85	2.89	2.42	1.88	1.38	1.39	1	1	7	122	122	116	123	144	0.00820	0.00820	0.06034
3	8	13	1.61	6.09	2.25	2.35	1.20	1.09	0.81	0.50	0	0	2	26	24	26	26	34	0	0	0.07692
3	8	14	2.34	6.12	2.19	2.19	1.65	1.20	1.11	0.59	0	0	0	28	28	28	28	39	0	0	0
3	8	20	1.67	5.96	2.69	2.72	1.18	1.50	0.69	0.59	1	0	1	30	31	30	31	44	0.03333	0	0.03333
3	8	21	1.40	6.44	2.51	2.58	1.45	1.08	0.54	0	1	1	5	28	28	24	29	39	0.03571	0.03571	0.20833
3	8	27	1.84	6.22	2.64	2.65	1.53	1.44	0.24	0.54	1	1	3	12	12	10	13	15	0.08333	0.08333	0.30000
3	8	28	2.15	6.32	2.30	2.33	1.19	1.15	0.80	1.00	0	0	4	33	33	29	33	39	0	0	0.13793
4	6	25	n.a.	6.19	2.25	2.37	1.96	0.77	0.59	0.82	3	4	11	114	113	106	117	195	0.02632	0.03540	0.10377
4	6	26	2.79	6.53	2.28	2.37	2.39	1.00	1.50	1.04	6	5	18	116	117	104	122	141	0.05172	0.04274	0.17308
4	7	1	2.01	7.18	2.22	2.26	1.80	1.33	0.60	0.56	1	0	19	77	78	59	78	111	0.01299	0	0.32203
4	7	2	2.39	5.72	1.44	1.71	2.03	1.39	1.72	1.10	2	4	30	115	113	87	117	144	0.01739	0.03540	0.34483

Table 6.2 Continued

BEACH	MONTH	DATE	Log10(bacterial count)								Number of ill swimmers			No. not ill swimmers			Overall		Ill/Not ill		
			St	Het	Ec	Fec	Str	Ent	Pam	Pat	GI	SKIN	ILL	GI	SKIN	ILL	Swimmers	People	GI	SKIN	ILL
4	7	3	2.70	6.72	3.20	3.23	0.85	1.93	1.70	1.34	9	2	19	82	89	72	91	116	0.10976	0.02247	0.26389
4	7	9	2.05	5.90	2.12	2.14	1.77	1.35	0	0	1	0	2	46	47	45	47	77	0.02174	0	0.04444
4	7	10	2.69	6.49	2.03	2.06	2.33	1.18	0.68	0.71	0	0	4	104	104	100	104	155	0	0	0.04000
4	7	16	2.60	6.56	2.61	2.66	1.76	1.59	1.00	0.83	5	0	7	94	99	92	99	115	0.05319	0	0.07609
4	7	17	2.77	5.99	2.10	2.16	2.17	1.56	1.79	1.60	4	1	8	94	97	90	98	129	0.04256	0.01031	0.08889
4	7	23	1.95	6.30	2.66	2.82	2.39	1.81	0.63	0.98	3	1	4	50	52	49	53	129	0.06000	0.01923	0.08163
4	7	24	1.60	6.66	2.51	2.57	1.58	1.29	0.24	0.30	5	1	12	166	170	159	171	307	0.03012	0.00588	0.07547
4	7	30	2.16	6.05	2.27	2.30	1.95	1.47	0	0.50	0	1	1	7	6	6	7	55	0	0.16667	0.16667
4	7	31	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1	0	1	22	23	22	23	n.a.	0.45455	0	0.04545
5	7	30	1.93	5.54	3.00	3.02	2.18	1.64	1.21	0.50	0	0	6	162	162	156	162	184	0	0	0.03846
5	7	31	2.58	6.69	3.68	3.76	2.86	2.70	2.15	2.03	0	0	0	0	0	0	0	1	n.a.	n.a.	n.a.
5	8	1	2.11	5.90	2.95	2.99	1.97	1.85	1.99	1.77	8	0	12	198	206	194	206	296	0.04040	0	0.06186
6	8	6	1.74	5.60	2.47	2.50	1.71	1.07	0.96	0.85	5	0	7	271	276	269	276	306	0.01845	0	0.02602
6	8	7	1.61	5.76	2.80	2.99	1.69	1.62	0.96	0.81	11	0	20	322	333	313	333	375	0.03416	0	0.06390
6	8	13	1.43	5.93	1.71	1.98	1.16	1.27	1.13	0.63	0	1	3	75	74	72	75	86	0	0.01351	0.04167
6	8	14	1.87	5.30	2.34	2.40	1.66	1.72	0.15	0.15	0	0	5	150	150	145	150	165	0	0	0.03448
6	8	20	1.08	5.63	2.39	2.40	1.65	1.57	0.42	0.15	0	1	7	81	80	74	81	96	0	0.01250	0.09459
6	8	21	2.00	6.02	2.49	2.59	1.81	1.62	0.54	0.24	3	0	6	179	182	176	182	205	0.01676	0	0.03409
6	8	27	1.81	5.24	1.83	2.12	1.20	0.83	0.42	0.48	2	0	5	51	53	48	53	59	0.03922	0	0.10417
6	8	28	1.40	5.45	1.67	1.69	0.83	1.10	0.24	0.24	0	0	3	68	68	65	68	78	0	0	0.04615

Legend:

Beach: 1 - Boyd; 2 - Claireville; 3 - Albion Hills; 4 - Heart Lake; 5 - Kelso; 6 - Professor's Lake.
Count: St - total staphylococci; Het - heterotrophs; Ec - E. coli; Fec - fecal coliforms; Str - fecal streptococci; ent - enterococci; pam - P. aeruginosa on mPA; pat - P. aeruginosa on mTIN.
Illness: GI - gastrointestinal; SKIN - skin symptoms; ILL - any symptom.
n.a. - not available.

between 0.50 and 0.75 indicate a moderate to good relationship. Values in excess of 0.75 reveal a very good relationship.

The data presented in Table 6.3 appear to be uncorrelated. In fact, at best, not even a fair relationship exists within these data. The order from best to worst correlations between bacterial densities and GI symptoms were: P. aeruginosa (on mPA), P. aeruginosa (on mTIN), fecal coliforms, E. coli, total staphylococci, the enterococci, heterotrophs, and fecal streptococci. However, for GI illness, of primary interest, from best to worst correlation, would be: fecal coliforms, E. coli, the enterococci, and fecal streptococci, because of their apparent associations with GI ailments (Lennette et al., 1985; Cabelli, 1982; Buchanan and Gibbons, 1974). Interestingly, all but two of the correlation coefficients were positive.

As expected, the best correlation between bacterial density and skin symptoms was displayed by the total staphylococci. All the other correlations were much poorer. Various species of the total staphylococci have been associated clinically with skin symptoms (Brown, 1983; Kloos and Jorgensen, 1985).

The correlation coefficients between overall illness and bacterial count, from best to worst, were: total staphylococci, P. aeruginosa (on mPA), P. aeruginosa (on mTIN), heterotrophs, fecal streptococci, enterococci, fecal colifroms, and E. coli.

Table 6.3 Correlation Coefficients Relating Bacterial Densities to Illness Symptoms (Data Analysed by Beach, Month, and Date)

Bacteria		GI	SKIN	ILL
Staphylococci		0.13287 0.3382 54	0.19720 0.1529 54	0.20491 0.1372 54
Enterococci		0.10197 0.4463 58	-0.13034 0.3295 58	-0.04810 0.7199 58
Heterotrophs		-0.01220 0.9275 58	0.09676 0.4700 58	0.13178 0.3241 58
<u>E. coli</u>		0.18234 0.1707 58	-0.06625 0.6212 58	-0.10919 0.4146 58
Fecal coliforms		0.18985 0.1535 58	-0.07494 0.5761 58	-0.10002 0.4551 58
Streptococci		-0.11991 0.3700 58	0.08275 0.5369 58	0.00689 0.9690 58
<u>P. aeruginosa</u>	(1)	0.22943 0.0832 58	0.02412 0.8574 58	0.19760 0.1371 58
	(2)	0.19291 0.1468 58	0.08991 0.5021 58	0.15065 0.2590 58

Values given given in vertical order are: r, p>/r/ under H_0:rho=0, and number of observations.

6.5 Linear regression models

Simple linear regression models were generated using PROC GLM (SAS, 1982c). The GLM procedure employs the method of least squares to fit general linear models. The functions of illness and bacterial count utilized were the same as those documented above in the correlation coefficient procedure (i.e. ill/not ill against $\log_{10}$ of the geometric mean of the bacterial count, for data classified by beach, month, and date). For these simple regression models, the data for the entire study population (n=9296) was incorporated, and also utilized the bacteriological data for all the days on which the epidemiological survey was conducted.

Linear regression models for GI illness in swimmers versus fecal coliforms, *E. coli*, and the enterococci have been investigated by Cabelli and his co-workers (op. cit.). Cabelli and his co-workers favoured the enterococci and *E. coli* as the optimal freshwater (and marine) bacterial indicators. In fact, the enterococci were favoured over *E. coli* (Dufour, 1985). Table 6.4 displays the regression models for these data, and Figures 6.1 to 6.3 depict the results graphically. Clearly, there was no dramatic relationship between GI illness and bacterial counts, because the correlation coefficients were all small. The gradient of the slopes of the fitted lines tended to zero. This suggested that there was no dramatic increase in GI

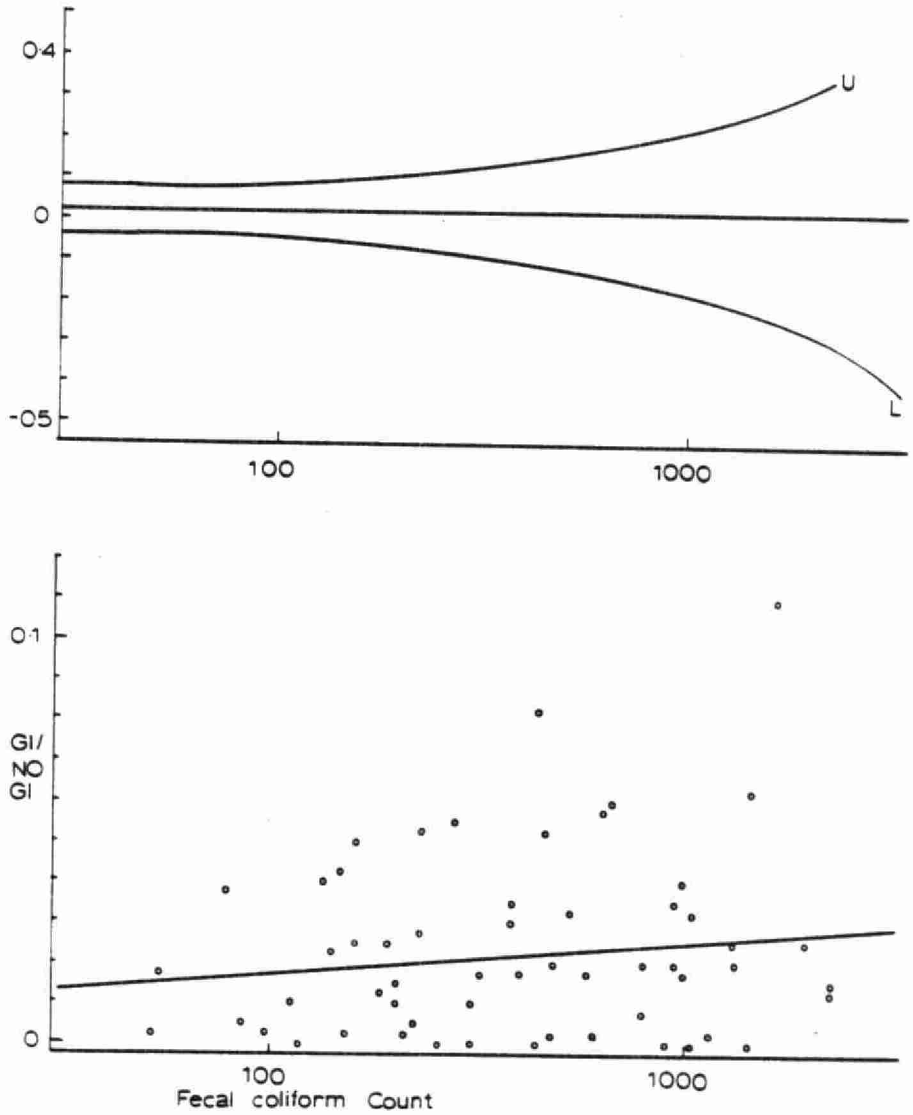

Figure 6.1 Unadjusted Simple Regression Model Showing the Odds of Swimmers Contracting Gastrointestinal Illness versus the Fecal Coliform Count

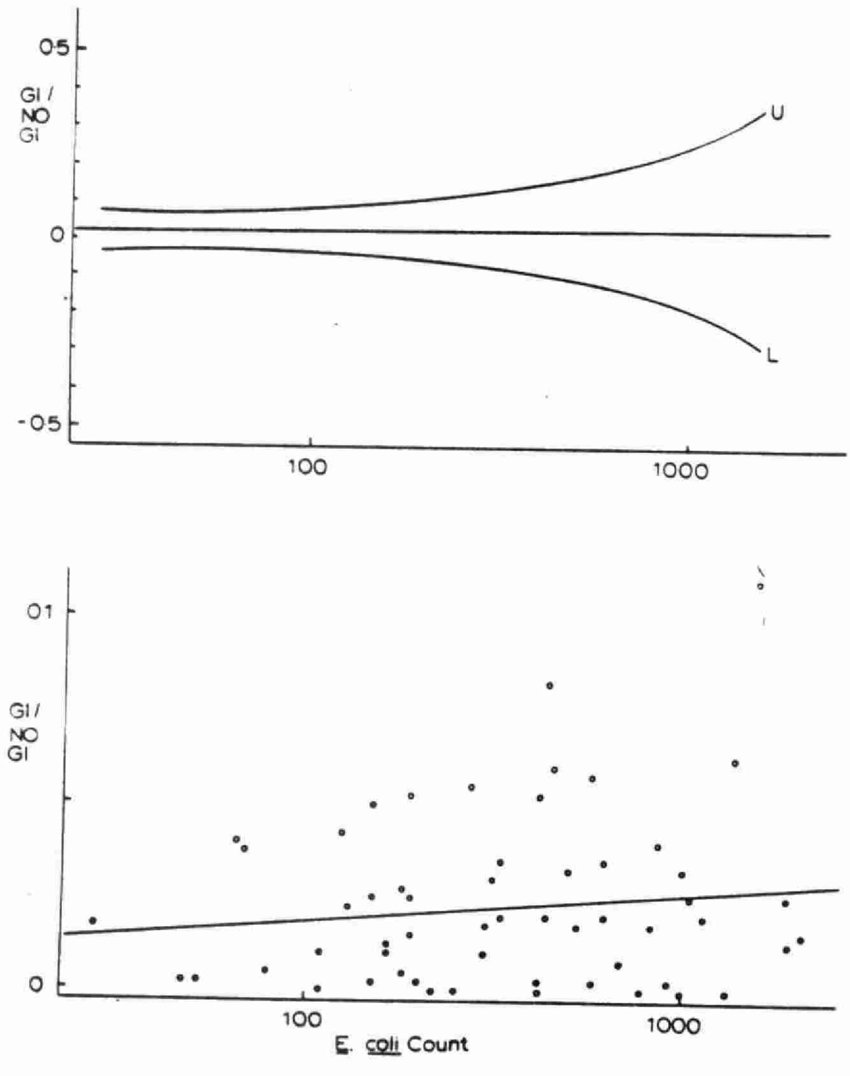

Figure 6.2 Unadjusted Simple Regression Model Showing the Odds of Swimmers Contracting Gastrointestinal Illness versus the *E. coli* Count

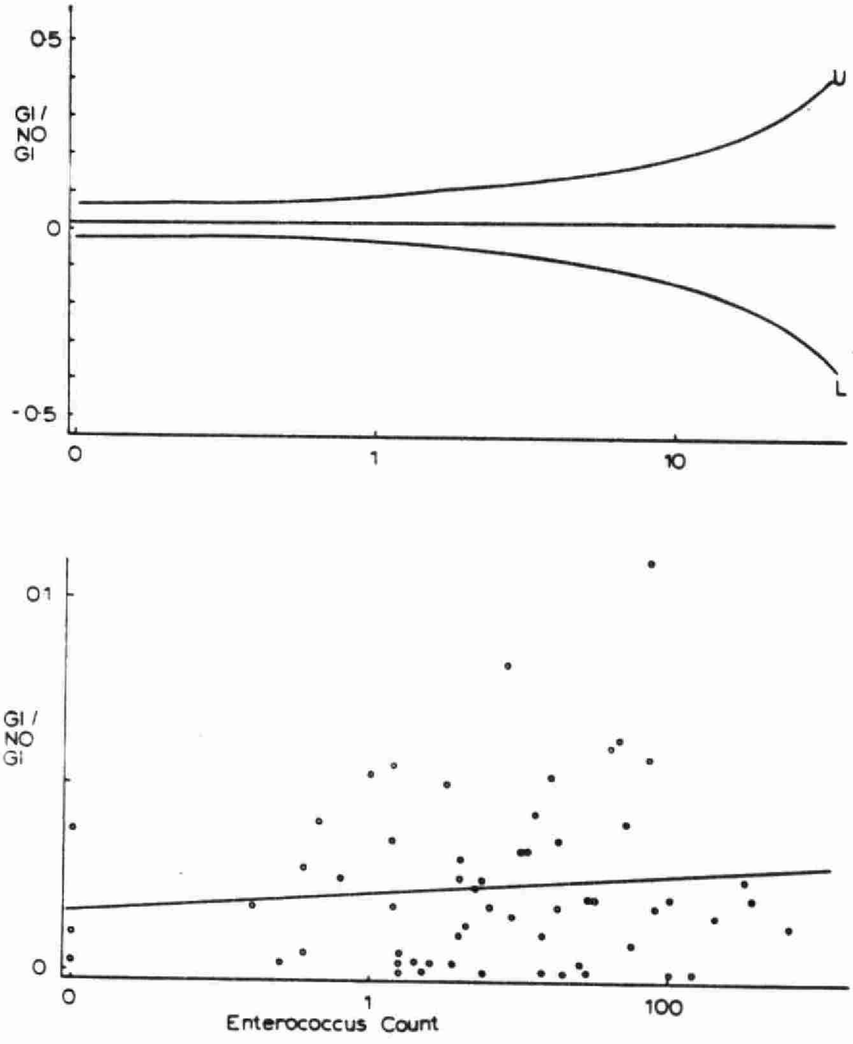

Figure 6.3 Unadjusted Simple Regression Model Showing the Odds of Swimmers Contracting Gastrointestinal Illness versus the Enterococcal Count

Table 6.4 Linear Regression Models Showing the Odds of Swimmers Contracting Gastrointestinal (GI) Illness versus the Bacterial Count

(1) GI SYMPTOMS VERSUS FECAL COLIFORMS:

Parameter	Estimate	t hor Ho: parameter=0	p>/t/	s.e. of estimate
Intercept:	-0.001	-0.07	0.9423	0.016
Count:	0.009	1.45	0.1535	0.006

Equation for line: $p/(1-p) = -0.001 + 0.009*\log_{10}(count)$
$r^2=0.036$, $r=0.190$
Cabelli's r=-0.08 for similar freshwater regression line (Dufour, 1985).

(2) GI SYMPTOMS VERSUS E. coli:

Parameter	Estimate	t for Ho: parameter=0	p>/t/	s.e. of estimate
Intercept	0	0.03	0.9771	0.016
E. coli	0.008	1.39	0.1707	0.006

Equation for line: $p/(1-p)= 0.008*\log_{10}(count)$
$r^2=0.033$, $r=0.182$
Cabelli's r=0.80 for similar freshwater regression line (Dufour, 1985).
Cabelli's equation: $y=-11.74+9.397*\log_{10}(count)$.

(3) GI SYMPTOMS VERSUS ENTEROCOCCI:

Parameter	Estimate	t for Ho: parameter=0	p>/t/	s.e. of estimate
Intercept	0.017	2.24	0.0292	0.008
Count	0.004	0.77	0.4463	0.005

Equaation for line: $p/(1-p)=0.017+0.004*\log_{10}(count)$
Cabelli's r=0.74 for similar freshwater regression line (Dufour, 1985).
Cabelli's equation: y=-6.278+9.40log10(Count).

illness with increasing bacterial count. None of the correlations were anywhere near as strong as those reported by Cabelli and his co-workers (Dufour, 1985), despite the differences in study methodologies.

Linear regression models were also generated for overall illness in swimmers versus: fecal coliforms, E. coli, enterococci, fecal streptococci, total staphylococci, and P. aeruginosa (on mPA). Only the best two models (i.e total staphylococci and P. aeruginosa), as measured by the highest correlation coefficients, are presented in Table 6.5 and Figures 6.4 and 6.5. In both cases, the gradient of the fitted line was positive, and the intercept fell above zero.

Finally, regression models were generated for skin symptoms in swimmers versus the total staphylococci because of their importance in previous studies (e.g. Brown, 1983; Seyfried et a., 1985b). These results are shown in Table 6.6 and Figure 6.6. The slope of the fitted line was positive and the intercept was also positive.

It is clear from all of these simple models that no strong relationship existed between bacterial count and the probability of illness in swimmers.

6.6 Multiple bacterial indicators

At present, investigators have generally pursued the debate concerning the relationship of bacterial count to illness rates with only a single bacterial indicator in

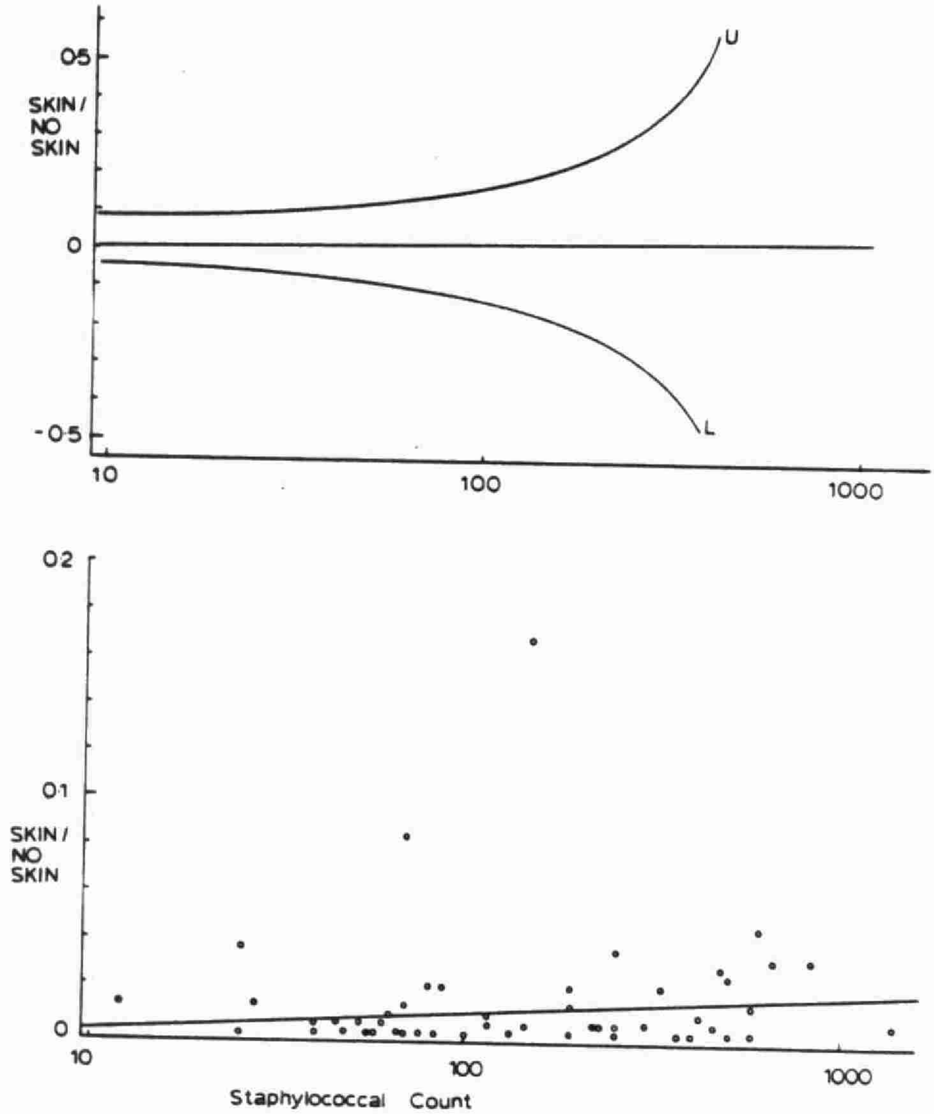

Figure 6.4 Unadjusted Simple Regression Model Showing the Odds of Swimmers Contracting Illness versus the Total Staphylococcal Count

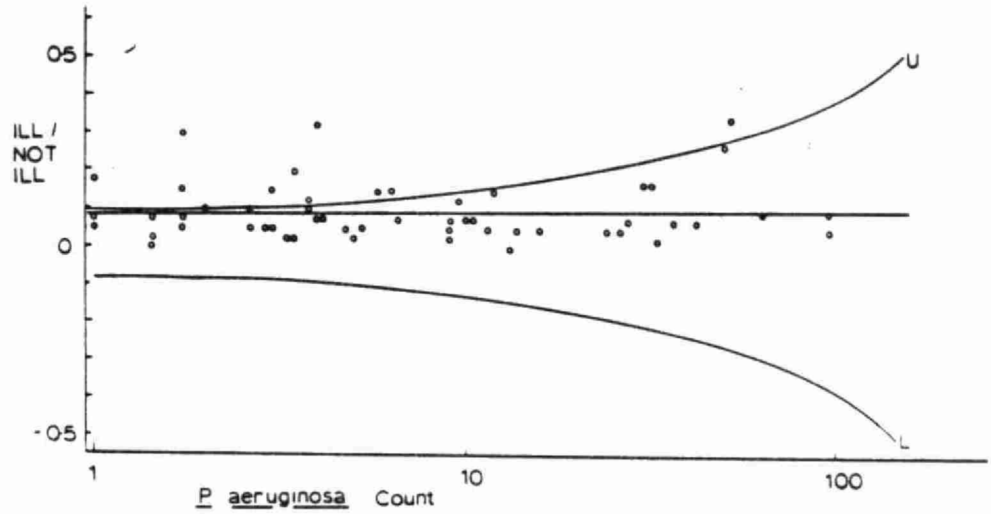

Figure 6.5 Unadjusted Simple Regression Model Showing the Odds of Swimmers Contracting Illness versus the P. aeruginosa (on mPA) Count

Table 6.5 Linear Regression Models Showing the Odds of Swimmers Contracting Illness versus the Bacterial Count

(1) OVERALL ILLNESS SYMPTOMS VERSUS TOTAL STAPHYLOCOCCI:

Parameter	Estimate	t hor Ho: parameter=0	p>/t/	s.e. of estimate
Intercept:	0.026	0.61	0.5430	0.042
Count:	0.028	1.51	0.1372	0.018

Equation for line: $p/(1-p) = 0.026 + 0.028*\log_{10}(\text{Count})$
$r^2=0.042$, $r=0.020$.

(2) OVERALL ILLNESS VERSUS _P. AERUGINOSA_:

Parameter	Estimate	t for Ho: parameter=0	p>/t/	s.e. of estimate
Intercept	0.070	4.55	0.0001	0.015
E. coli	0.022	1.51	0.1371	0.015

Equation for line: $p/(1-p)= 0.070 + 0.022*\log10(\text{count})$
$r^2=0.039$, $r=0.20$.

Table 6.6 Linear Regression Models Showing the Odds of Swimmers Contracting Skin problems

(1) SKIN SYMPTOMS VERSUS TOTAL STAPHYLOCOCCI:

Parameter	Estimate	t hor Ho: parameter=0	p>/t/	s.e. of estimate
Intercept:	-0.006	-0.58	0.5647	0.011
Count:	0.007	1.45	0.1529	0.005

Equation for line: $p/(1-p) = 0.006 + 0.007*\log_{10}(\mathrm{Count})$
$r^2=0.039$, $r=0.200$.

each model. However, the question arises as to whether or not beach closure might be assessed better if a multiple bacterial index was used.

This study therefore attempted, in a preliminary way, to investigate the possible use of multiple bacterial indicators. The advantage of being able to select a small number of bacterial indicators was important because it would drastically reduce the time, labour, and cost of laboratory determinations. In order to investigate this question, the RSQUARE procedure of SAS (1982d) was used. This procedure generates all possible regression coefficients for one or more dependent variables and a collection of independent variables, and evaluates every combination of the independent variables with the dependent variable. For each model, the square of the multiple correlation coefficient (R^2) and Mallow's C_p statistic was calculated (SAS, 1982d).

The RSQUARE procedure, using swimmers only, was used to test various combinations of three types of bacterial indivators in relation to both GI illness and overall illness. The dependent variables were chosen on the basis of the studies of Cabelli and co-workers (op. cit.), Brown (1983), and Seyfried _et al_. (1985a,b). The results of the procedure appear in Table 6.7 for overall illness, and Table 6.8 for GI illness.

In order to select the best possible combination between overall illness and bacterial indicators, it was decided to rule out the use of heterotrophs, because of

their unlikely association with illness (Buchanan and Gibbons, 1974), and to incorporate only one of the following in a model: fecal coliforms, E. coli, and the enterococci, because each of them have primarily been associated with GI illness (Dufour, 1982). The fecal streptococci were not included in the latter list, nor selection of best models, because they were considered to be of less importance. Only one of the P. aeruginosa determinations was used (the mTIN medium composition is not published). Thus, Table 6.7 displays the three best models, in order of the highest to lowest correlations, using the criteria mentioned, for overall illness:

1. The total staphylococci, the enterococci, and P. aeruginosa (on mPA).

2. The total staphylococci, the enterococci, and P. aeruginosa (on mTIN).

3. The total staphylococci, fecal coliforms, and P. aeruginosa (on mPA).

4. The total staphylococci, E. coli, and P. aeruginosa (on mPA).

Routine clinical and environmental laboratories might well prefer the third or fourth models listed because monitoring of the enterococci may not be standard practice, and because publication of the mTIN medium for the isolation of P. aeruginosa is still in progress.

The data in Table 6.8 suggested that the four best three models, as measured using the criteria mentioned above, are:

Table 6.7 Regression Models for Overall Illness in Swimmers versus Combinations Involving Three Types of Bacteria

R-SQUARE	C(P)	VARIABLES IN MODEL
0.201	16.06	het, fec, str
0.203	15.90	ec, fec, ent
0.204	15.87	ec, str, pam
0.205	15.78	het, fec, ent
0.207	15.57	het, ec, str
0.208	15.55	str, pam, pat
0.214	15.06	ec, str, ent
0.216	14.90	het, ent, pat
0.216	14.83	str, ent, pam
0.216	14.83	het, fec, pat
0.216	14.82	het, ec, ent
0.217	14.80	het, str, pat
0.218	14.73	het, ec, fec
0.218	14.66	het, ec, pat
0.220	14.53	ec, fec, pam
0.224	14.22	fec, pam, pat
0.227	14.00	fec, ent, pam
0.233	13.46	ec, pam, pat
0.243	12.66	ec, ent, pam
0.253	11.83	het, str, pam
0.253	11.82	het, fec, pam
0.254	11.75	het, ec, pam
0.254	11.75	het, ent, pam
0.256	11.60	het, pam, pat

Table 6.7 Continued

R-SQUARE	C(P)	VARIABLES IN MODEL
0.304	7.71	st, fec, pat
0.304	7.66	st, ec, pat
0.306	7.52	st, str, ent
0.318	6.58	st, ec, pam
0.319	6.48	st, fec, pam
0.322	6.23	st, str, pat
0.326	5.89	st, ec, fec
0.327	5.81	st, ent, pat
0.327	5.78	st, pam, pat
0.333	5.32	st, het, ec
0.334	5.28	st, het, fec
0.336	5.08	st, het, pat
0.339	4.85	st, fec, str
0.340	4.72	st, str, pam
0.341	4.67	st, het, ent
0.344	4.47	st, ent, pam
0.348	4.12	st, het, pam
0.348	4.10	st, fec, ent
0.350	3.92	st, ec, str
0.352	3.82	st, het, str
0.366	2.64	st, ec, ent

Legend: See Table 6.7

het - $\log_{10}$(heterotropic count)
fec - $\log_{10}$(fecal coliform count)
str - $\log_{10}$(streptococcal count)
pam - $\log_{10}$(P. aeruginosa count) on mPA
pat - $\log_{10}$(P. aeruginosa count) on mTIN
ent - $\log_{10}$(enterococcal count)
st - $\log_{10}$(staphylococcal count)

C(P) - Mallow's Cp statistic

Table 6.8 Regression Models for Gastrointestinal (GI) Illness in Swimmers versus Combinations Involving Three Types of Bacteria

R-SQUARE	C(P)	VARIABLES IN MODEL
0.196	22.56	het, fec, str
0.198	22.39	ec, str, pat
0.198	22.38	ec, fec, str
0.198	22.38	het, ec, pat
0.204	21.87	het, ec, str
0.207	21.57	het, str, pam
0.207	21.55	het, pam, pat
0.207	21.55	het, ent, pam
0.213	21.03	ec, fec, pam
0.213	21.03	fec, pam, pat
0.216	20.82	fec, str, pam
0.217	20.67	het, fec, pam
0.219	20.52	fec, str, ent
0.219	20.51	het, fec, ent
0.219	20.50	ec, pam, pat
0.220	20.45	het, ec, pam
0.223	20.18	ec, str, pam
0.233	19.26	het, ec, ent
0.233	19.23	fec, ent, pat
0.234	19.21	ec, fec, ent
0.234	19.16	ec, str, ent
0.247	18.01	ec, ent, pat
0.263	16.61	fec, ent, pam
0.275	15.51	ec, ent, pam
0.313	12.17	st, fec, pat
0.313	12.13	st, ec, pat
0.315	11.99	st, het, fec
0.316	11.89	st, het, ec
0.320	11.56	st, fec, pam
0.320	11.55	st, ec, pam
0.320	11.52	st, het, pat
0.321	11.48	st, pam, pat
0.321	11.40	st, ec, fec
0.322	11.37	st, het, ent
0.326	10.97	st, het, pam
0.337	10.00	st, str, ent
0.345	9.33	st, het, str
0.349	8.91	st, ent, pam
0.354	8.50	st, ent, pat
0.368	7.24	st, str, pat
0.368	7.22	st, str, pam
0.397	4.62	st, fec, ent
0.412	3.34	st, ec, ent
0.429	1.83	st, fec, str
0.438	1.01	st, ec, str

Legend: See Table 6.7

1. Total staphylococci, the enterococci, and *P. aeruginosa* (on mTIN).

2. Total staphylococci, the enterococci and *P. aeruginosa* (on mPA).

3. Total staphylococci, *E. coli*, and *P. aeruginosa* (on mPA).

4. Total staphylococci, fecal coliforms, and *P. aeruginosa* (on mPA).

Routine clinical and environmental laboratories might prefer the third or fourth models, for the reasons given above. Some investigators dislike the use of total staphylococci and *P. aeruginosa*, as conventional wisdom suggests that they are not simply related to GI illness, and they may favour models involving fecal coliforms, *E. coli*, and perhaps the enterococci. Data are given in Table 6.9 for GI symptoms and two of the following: *E. coli*, enterococci, and fecal coliforms. The best RSQUARE statistics generated were, in order from highest tolowest:

1. *E. coli* and enterococci.

2. fecal coliforms and the enterococci.

The RSQUARE models are intended only as a possible pointer to more complex models which should be approached using a multivariate method.

6.7 Summary

The ideas embodied in this chapter were presented as a basic framework for further analysis. They were based on

simple models where confounding variables were given no consideration. While the models undoubtedly provide useful comparisons with the work of Cabelli and his co-workers (op. cit.), they should not be used as the basis for recreational water quality guidelines.

Table 6.9 Regression Models for Gastrointestinal (GI) Illness in Swimmers versus Combinations Involving Two Types of Bacteria

R-SQUARE	C(P)	VARIABLES IN MODEL
0.117	27.59	str, ent
0.136	25.88	het, str
0.139	25.62	het, ent
0.146	25.04	ent. pat
0.153	24.42	str, pat
0.174	22.54	pam, pat
0.175	22.45	ent, pam
0.179	22.05	str, pam
0.180	21.98	fec, pat
0.185	21.53	het, fec
0.186	21.49	fec, str
0.186	21.48	het, pat
0.186	21.44	ec, pat
0.189	21.19	ec, fec
0.191	21.08	het, ec
0.196	20.60	ec, str
0.203	19.96	fec,pam
0.207	19.57	ec, pam
0.207	19.57	het, pam
0.218	18.60	fec, ent
0.233	17.27	ec, ent
0.310	10.43	st, fec
0.312	10.27	st, ec
0.312	10.27	st, ent
0.313	10.17	st, pat
0.314	10.10	st, het
0.320	9.56	st, pam
0.326	8.99	st, str

Legend: refer to Table 6.7

CHAPTER 7

MULTIVARIATE ANALYSIS - LOGISTIC REGRESSION MODELLING

7.1 Introduction

The relationship between swimming-related illness and the bacteriological quality of fresh recreational waters has been described in terms of simple linear models (Chapter 6; Dufour, 1982; 1985). However, it is crucial to investigate and remove, as far as possible, the possibility of bias arising from the effects of confounding variables, as well as to identify the significance of particular risk factors for disease. For these reasons, multivariate analysis, or more specifically, logistic regression modelling, was undertaken upon the data.

The logistic model was first systematically used for the analysis of the individual and joint effects of a set of variables on the risk of disease (Schlesselman, 1982; Cornfield _et al_., 1961; Cornfield, 1962). In the logistic model, the probability of disease depends upon a set of variables x_1, x_2, ... x_p, in the manner (Schlesselman, 1982):

$$p_x = p(d=1 | x)$$

$$p_x = 1/(1+\exp(-(B_o + B_1 x_1 + \ldots + B_p x_p))),$$

d denotes either the presence (d=1) or absence (d=0) of disease, and x specifies a set of p variables, $x=(x_1, x_2, \ldots, x_p)$ (Schlesselman, 1982). The variables $x_1, \ldots, x_p$

can represent any potential risk factor or confounding variables, functions of them, or interactions of concern (Schlessman, 1982). The B's are parameters which portray the effects of the x's on the probability, or risk, of disease (Schlesselman, 1982).

7.2 Methods used for logistic regression modelling

The SAS (1982e) FUNCAT procedure was used to generate predictive models of swimming-related illness. FUNCAT models FUNctions of CATegorical responses as a linear model incorporating linear and log-linear categorical models, as well as logistic regressions. For this investigation, FUNCAT was used to model functions of categorical responses by linear logistic regression.

In FUNCAT, the model can be described by the response and design effects (SAS, 1982e). The response is categorical because the frequency counts for each level are measured, and these counts are assumed to be multinomially distributed. The design effects group the experimental units into samples or populations, and the observations for a population have the same values for all of the design variables. Each population has a different multinomial distribution for the response counts, for example:

SAMPLE	RESPONSE 1	...	RESPONSE r	SAMPLE SIZE
1	n_{11}	...	n_{1r}	n_1
2	n_{21}	...	n_{2r}	n_2
.				
.				
.				
s	n_{s1}	...	n_{sr}	n_s

For each sample i, the probability of the jth response ($_{ij}$) is estimated by $p_{ij}=n_{ij}/n_i$, and these estimates are employed to construct values for some function defined on the response probabilities. The function of true probabilities is assumed to follow a linear model with regard to the design structure of the samples. FUNCAT applies the same function to every sample population. The model can be written as follows:

$$f(\Pi_i)=X_iB+\sum_i \text{ for } i=1 \text{ to } s, \text{ where}$$

$$\Pi_i=(\Pi_{i1}, \Pi_{i2}, \ldots, \Pi_{ir}).$$

The function f can be any combination of log, exponential, and linear transformations. The design matrix X and the form of the parameters are ascertained by design effects (i.e.: main effects, crossed effects, nested effects, and special nested effects).

Two estimation methods are available in FUNCAT:

1. The weighted least-squares method minimizes the weighted sum of squares of the error in the model.
2. The maximum likelihood method adjusts the parameters of the linear model to maximize the value of the joint multinomial likelihood function of the responses (SAS,

1982e).

This study employed the maximum likelihood method to aid in selecting the most appropriate model(s). FUNCAT also provided parameter estimates and approximate chi-square statistics to determine the relative importance of the factors in the model (Armitage, 1971).

For the purpose of linear logistic regression modelling in this study, a FUNCAT predictive model may be written in this way (Schlesselman, 1982):

$$\text{logit } p = \ln(p/1-p) = \alpha + B_1x_1 + B_2x_2 + \ldots + B_nx_n,$$

where p represents the probability of becoming ill, 1-p is the probability of remaining free of illness, α is the intercept or mean of the illness rate, the x's are variables in the model, and the B's represent the coefficients of the terms in the model (Schlesselman, 1982).

A particular illness (the outcome or dependent variable) and the bacterial count (an independent variable), specifically, $\log_e$ of the geometric mean of the count, were always included in the model, as well as other independent variables which significantly assisted in explaining the variation in response. Thus, in choosing a particular model, all the important factors were entered into the model, and then factors with a chi-square p-value greater than 0.05 were dropped, one at a time, in order from the largest to smallest p-value. For each of the

steps, if the rounded iteration 0 loglikelihood minus the rounded final iteration log likelihood (for the larger model subtracted from the smaller one) yielded a value which was significant at the 5% level (when one also considers the degrees of freedom, by subtraction), then the factor was kept in the model. Due to the effect of rounding, this procedure occasionally led to the retention of factors with p values slightly above 0.05, but it was felt that such borderline factors were important to the particular models.

The resultant models could be used to predict illness from the observed data. If these predictive estimates were positive in sign, then the particular category of that factor contributed to the probability of illness, if all other factors were held constant. The effects of each of the factors in the model, including the intercept, were provided. Generally speaking, the factors are only of interest if the p-value associated with the given chi-square value is less than, or equal to, 0.05, implying significance at the 5% level.

FUNCAT logistic regression modelling was undertaken for:

1. swimmers, waders, and persons who did not enter the water (n=8420), collectively, and
2. swimmers only (n=6653).

In order to plot the predicted relationship between illness in swimmers and bacterial count, a subsequent additional linear logistic model was fitted. This modelling

used the observed logits ($\log_e(p/1-p)$, probability of illness), as the dependent variable, and the $\log_{10}$ of the geometric mean of the bacterial count ($\log_{10}$ was used because bacteriologists, by convention, tend to treat data in this format) as the independent variable. The slope of the independent variable was thus forced to be that of that associated with the $\log_{10}$ of the geometric mean of the bacterial count value (i.e: the estimate for that variable) from the original full predictive FUNCAT model (i.e.: the original model which included all the important factors). This was done using the GLIM package (developed for graphic and visual purposes e.g.: Baker and Nelder, 1978; Nelder and Wedderburn, 1972) on the UNIX operating system at the University of Toronto.

7.3 Raw data for logistic regression modelling

The raw data utilized for logistic regression modelling (n=8420) is presented in Table 9.4 of the Appendix.

7.4 Logistic regression models for swimmers, waders, and persons who did not enter the water

Logistic regression models were generated for swimmers, waders, and persons who did not enter the water (n=8420), for various combinations of reported illnesses, bacterial counts, and other relevant factors. Various

combinations of reported illness category and bacterial count were chosen for invesigation. Overall illness was modelled (i.e. tested) against the total staphylococci, fecal coliforms, E. coli, the enterococci, the fecal streptococci, and P. aeruginosa (on mPA and on mTIN). GI illness was modelled versus fecal coliforms, E. coli, the enterococci, and the fecal streptococci. Ear problems were modelled against P. aeruginosa (on mPA and mTIN). Skin, eye, and respiratory problems were modelled versus the total staphylococci. Heterotrophs were not used in modelling because their direct role in depicting and describing illness causation, or their indirect roles, were deemed unlikely. In each case, the bacteria-illness combinations were considered to be likely cause- or indicator-effect combinations.

The illness risks associated with water exposure (i.e: swimmers, waders, or persons who did not go into the water) were of particular concern. In order to examine the possibility of dose-response effects related to water exposure, bacterial density was given further consideration. Since persons who did not enter the water were not exposed to bacteria in the water, whereas swimmers were thought to bear the effects of full bacterial exposure to the body, and waders were considered to receive only a proportion of the exposure, the following factors were introduced into the models to take into account this feature of the data:

1. for persons who did not enter the water, the natural

logarithm of the geometric mean of the bacterial count was considered to be zero,

2. for persons who swam, the natural logarithm of the geometric mean of the bacterial count remained the same, and

3. for waders, the natural logarithm of the geometric mean of the bacterial count was multiplied by an intermediate factor of 0.3.

The factor of 0.3 used for the wading population was selected in order to minimize the effect of what was considered to be a very minor route of exposure to bacteria in the water. Clearly, issue could be taken with the magnitude of this factor, however it will be shown that extreme differences in the models do not ensue even if the factor is radically altered.

Several variables were considered in generating the models, including the effects of: the function of bacterial density (count - generated by the above mentioned method), contact persons, age, swimming four days before or three days after the interview day, variation in beaches and interviewers, sex, Italian background, food and drink consumption, and month (because various newspapers printted stories about the beaches during July and August of 1983). Reporting by the contact person about the subject of swallowing water, head immersion, and duration of water exposure was not considered to be of adequate quality, since both contact persons and the subjects rarely appeared to take note of these activities. Furthermore, some

interactions between parameters were tested (e.g: beach and function of bacterial density, and beach plus food), but they did not emerge as being important in the models.

7.4.1 Overall illness models

The model for overall illness versus the total staphylococci appears in Table 7.1. As an example, the following calculations were performed to investigate the results of this model more fully:

$$\text{logit}(p) = \log_e(p/1-p) = -2.287^a +$$

$$0.029 * \log_e(\text{total staphylococcal count}) * f,$$

where a is the mean illness rate (intercept), and f takes the value 0 for persons who did not enter the water, 0.3 for waders, and 1 for swimmers,

+0.425 (if contact person)
-0.425 (if not contact person)

+0.143 (if swam or went in the water four days before, or three days after interview)
-0.143 (if did not swim or go into the water four days before, or three days after interview)

-0.028*(age)

-0.109 (interviewed at beach 1 - Boyd C.A. (Conservation Area))
+0.191 (interviewed at beach 2 - Claireville C.A.)
+0.207 (interviewed at beach 3 - Albion C.A.)
+0.444 (interviewed at beach 4 - Heart Lake C.A.)
-0.330 (interviewed at beach 5 - Kelso C.A.)
-0.403 (interviewed at beach 6 - Professor's Lake)

-0.193 (if interviewed by interviewer 1)
+0.907 (if interviewed by interviewer 2)
+0.756 (if interviewed by interviewer 3)
+0.078 (if interviewed by interviewer 4)
-0.773 (if interviewed by interviewer 5)
+0.467 (if interviewed by interviewer 6)
-0.225 (if interviewed by interviewer 7)

Table 7.1 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)*	O.R.	95%c.l.
Intercept	1	-2.827	0.226	0.0001 (0.0001)	n.a.	n.a.
Stwetb	1	0.0249	0.070	0.7224 (0.7224)	1.03	0.89, 1.18
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.143	0.046	0.0020 (0.0020)	1.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.109	0.158	0.4845	n.a.	n.a., n.a.
Beach2	1	0.191	0.133	0.1491	n.a.	n.a., n.a.
Beach3	1	0.207	0.097	0.0328	n.a.	n.a., n.a.
Beach4	1	0.444	0.121	0.0003	n.a.	n.a., n.a.
Beach5	1	-0.330	0.208	0.1125 (0.0005)	n.a.	n.a., n.a.
Interv1	1	-0.193	0.494	0.6961	n.a.	n.a., n.a.
Interv2	1	0.907	0.315	0.0039	n.a.	n.a., n.a.
Interv3	1	0.756	0.174	0.0001	n.a.	n.a., n.a.
Interv4	1	0.078	0.192	0.6857	n.a.	n.a., n.a.
Interv5	1	-0.773	0.403	0.0554	n.a.	n.a., n.a.
Interv6	1	0.467	0.167	0.0052	n.a.	n.a., n.a.
Interv7	1	-0.225	0.167	0.1782	n.a.	n.a., n.a.
Interv8	1	0.661	0.166	0.0001	n.a.	n.a., n.a.
Interv9	1	0.629	0.156	0.0001	n.a.	n.a., n.a.
Interv10	1	-1.354	0.940	0.1496	n.a.	n.a., n.a.
Interv11	1	-0.908	0.677	0.1798	n.a.	n.a., n.a.
Interv12	1	-0.340	0.219	0.1208	n.a.	n.a., n.a.
Interv13	1	0.580	0.172	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.104	0.045	0.0225 (0.0225)	0.81	0.68, 0.97
Wadeswim1	1	0.075	0.165	0.6496	2.12	0.96, 4.70
Wadeswim2	1	0.602	0.237	0.0111 (0.0120)	3.59	1.34, 9.61

Table 7.1 (continued).

LEGEND FOR TABLES PRODUCED FROM FUNCAT MODELS (Chapter 7)

* -	In this chapter, one should refer to these values in order to assess relevance to the model
df -	Degrees of freedom
S.E. -	Standard Error
O.R. -	Odds Ratio
95%c.l. -	95% confidence limits
	E.g. for FUNCAT:

Variable Design Columns

A	A(1)	A(2)
1	1	0
2	0	1
3	-1	-1

Variable Design Columns

B	B(1)
1	1
2	-1

Stwetb etc. -	$\log_e$ geometric mean of count, multiplied 0 for persons not entering the water, 0.3 for waders, and 1 for Swimmers.
Newcp -	=1 for contact person, =2 for not contact person
Newsba -	=1 for persons who swam four days before, or three days after the interview date, and 2 for other persons.
Age -	Coded exactly by year
Beach 1 -	Boyd C.A.
2 -	Claireville C.A.
3 -	Albion Hills C.A.
4 -	Heart Lake C.A.
5 -	Kelso C.A.
6 -	Professor's Lake
Interv -	14 interviewers, numbered 1 to 14.
Sex -	1=male, 2=female.
Wadeswim -	1=waders, 2=Swimmers, 3=persons who did not enter the water.

+0.661 (if interviewed by interviewer 8)
+0.629 (if interviewed by interviewer 9)
-1.354 (if interviewed by interviewer 10)
-0.908 (if interviewed by interviewer 11)
-0.340 (if interviewed by interviewer 12)
+0.580 (if interviewed by interviewer 13)
-0.285 (if interviewed by interviewer 14)

-0.104 (if male)
+0.104 (if female)

+0.075 (if wader)
+0.602 (if swimmer)
-0.667 (if the person did not enter the water).

Refering to Table 7.1, the factors included in the model were (in order of importance to the model): contact person (chi-square p-value=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), swimming before or after the interview day (p=0.0020), wadeswim (i.e. category of water exposure; p=0.0120), sex (p=0.0225), and the function of the bacterial count (p=0.7224). There was no evidence that the last factor was important in the prediction of reported illness, unlike the other factors which were present in the model.

The odds ratios and associated 95% confidence limits provide another aspect to the interpretation of these results. It is conventional to consider factors as being potentially important if the odds ratio is roughly 2.00 or more. In addition, 95% confidence limits which include the value 1.00 are considered not to be significant at the 5% level.

It can be seen from Table 7.1 that the function of the bacterial count had little effect on the risk of illness in this model. Younger persons had greater odds of becoming ill than did older persons. Males had slightly, but

significantly, decreased risk of illness versus females. Swimming before or after the interview day produced a slightly, but significantly, increased risk over those who did not swim before or after the interview day. Contact persons appeared to display significantly increased risk of illness over those who were not contact persons. Throughout this chapter, the risks associated with various illnesses were based upon reported results.

Presumably, higher risks of illness associated with contact persons and the slightly higher risk of illness associated with females were due to their tendency to report illness more often than their respective counterparts. Once again, it is wise to keep this in mind, throughout this entire chapter.

The category of water exposure (wadeswim was coded 1 for waders, 2 for swimmers, and 3 for persons who did not enter the water) revealed that waders were at elevated risk, when they were compared to persons who did not go into the water. The same held true for swimmers, but for them the risk was even greater. Throughout this chapter, both waders and swimmers were compared to persons who did not go into the water for odds ratio, or risk, purposes.

Subsequent models will be presented, but attention will be concentrated mainly upon risks associated with water exposure category, functions of bacterial density, and noteably high odds ratio values.

In Table 7.2, the model for overall illness versus fecal coliforms is presented. The factors included in the

Table 7.2 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus Fecal Coliforms						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.676	0.235	0.0001 (0.0001)	n.a.	n.a.
Fecwetb	1	-0.037	0.056	0.5109 (0.5109)	0.96	0.86, 1.08
Newcp	1	0.426	0.054	0.0001 (0.0001)	2.34	1.90, 2.90
Newsba	1	0.143	0.046	0.0019 (0.0019)	1.33	1.11, 1.59
Age	1	-0.027	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.044	0.156	0.7803	n.a.	n.a. n.a.
Beach2	1	0.225	0.111	0.0437	n.a.	n.a. n.a.
Beach3	1	0.173	0.098	0.0765	n.a.	n.a. n.a.
Beach4	1	0.419	0.129	0.0012	n.a.	n.a. n.a.
Beach5	1	-0.320	0.208	0.1238 (0.0002)	n.a.	n.a. n.a.
Interv1	1	-0.230	0.497	0.6441	n.a.	n.a., n.a.
Interv2	1	0.902	0.305	0.0031	n.a.	n.a., n.a.
Interv3	1	0.770	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.075	0.192	0.6971	n.a.	n.a., n.a.
Interv5	1	-0.785	0.404	0.0522	n.a.	n.a., n.a.
Interv6	1	0.480	0.168	0.0044	n.a.	n.a., n.a.
Interv7	1	-0.226	0.167	0.1746	n.a.	n.a., n.a.
Interv8	1	0.681	0.166	0.0001	n.a.	n.a., n.a.
Interv9	1	0.647	0.157	0.0001	n.a.	n.a., n.a.
Interv10	1	-1.367	0.940	0.1459	n.a.	n.a., n.a.
Interv11	1	-0.940	0.678	0.1656	n.a.	n.a., n.a.
Interv12	1	-0.320	0.221	0.1480	n.a.	n.a., n.a.
Interv13	1	0.579	0.171	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.104	0.045	0.0224 (0.0224)	0.81	0.68, 0.97
Wadeswim1	1	0.029	0.166	0.8586	2.37	1.08, 5.20
Wadeswim2	1	0.806	0.224	0.0003 (0.0003)	5.16	2.02, 13.16

model were the same as those found in the previous model, that is: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0002), swimming before or after the interview day (p=0.0002), wadeswim (p=0.0003), sex (p=0.0224), and the function of the bacterial count (p=0.5109; but the estimate was negative). There was no evidence in this model that the last factor was important in prediction of reported illness.

The function of bacterial density appears, once again, to have little effect on the risk of illness. As shown in the previous model, contact persons had significantly elevated illness risks. The same comments apply for age, sex, and swimminng before or after,, as reported in the previous model. In addition, the same comments for waders and swimmers apply as for the previous model. However, the risk for swimmers was even higher than in the model listed in Table 7.1.

The model for overall illness versus E. coli may be found in Table 7.3. The factors included in the model were the same as those for the previous models, that is: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), wadeswim (p=0.0001), swimming before or after the interview day (p=0.0019), sex (0.0223), and the function of the bacterial count (p=0.3243), but the estimate was negative. Interestingly, once again, there was no evidence to suggest that the last factor was important in the prediction of reported illness. Refering to the odds ratio associated with the model, exactly the same comments

Table 7.3 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus E. coli						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.636	0.228	0.0001 (0.0001)	n.a.	n.a.
Ecwetb	1	-0.053	0.054	0.3243 (0.3243)	0.95	0.85, 1.05
Newcp	1	0.426	0.054	0.0001 (0.0001)	2.34	1.90, 2.90
Newsba	1	0.143	0.046	0.0019 (0.0019)	1.33	1.11, 1.59
Age	1	-0.027	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.026	0.155	0.8655	n.a.	n.a., n.a.
Beach2	1	0.231	0.112	0.0385	n.a.	n.a., n.a.
Beach3	1	0.166	0.096	0.0829	n.a.	n.a., n.a.
Beach4	1	0.403	0.129	0.0017	n.a.	n.a., n.a.
Beach5	1	-0.309	0.208	0.1379 (0.0001)	n.a.	n.a., n.a.
Interv1	1	-0.240	0.496	0.6285	n.a.	n.a., n.a.
Interv2	1	0.912	0.305	0.0028	n.a.	n.a., n.a.
Interv3	1	0.775	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.072	0.191	0.7053	n.a.	n.a., n.a.
Interv5	1	-0.791	0.404	0.0504	n.a.	n.a., n.a.
Interv6	1	0.486	0.168	0.0039	n.a.	n.a., n.a.
Interv7	1	-0.228	0.167	0.1718	n.a.	n.a., n.a.
Interv8	1	0.685	0.165	0.0001	n.a.	n.a., n.a.
Interv9	1	0.651	0.157	0.0001	n.a.	n.a., n.a.
Interv10	1	-1.374	0.940	0.1438	n.a.	n.a., n.a.
Interv11	1	-0.950	0.678	0.1610	n.a.	n.a., n.a.
Interv12	1	-0.317	0.220	0.1497	n.a.	n.a., n.a.
Interv13	1	0.577	0.171	0.0008 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.104	0.045	0.0223 (0.0223)	0.81	0.68, 0.97
Wadeswim1	1	0.018	0.165	0.9118	2.44	1.13, 5.26
Wadeswim2	1	0.857	0.211	0.0001 (0.0001)	5.65	2.33, 13.74

apply as those outlined for the previous model.

The model for overall illness versus the enterococci is shown in Table 7.4. The factors included in this model were the same as for the two previous models and included: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), wadeswim (p=0.0001), swimming before and after (p=0.0020), sex (p=0.0001), and the function of the bacterial density (p=0.3664; but the estimate was negative). There was no evidence to suggest that the bacterial density was important in the prediction of reported illness (just as in previous models).

From the odds ratio data, it is apparent that the same comments are applicable for the factors involved as those for the previous model.

In Table 7.5, the model for the overall illness versus the fecal stretococci is presented. The following factors were included in this model: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), swimming before or after (p=0.0021), wadeswim (p=0.0007), sex (p=0.0226; but the estimate was negative), and the only factor for which there was no strong evidence that it contributed to the prediction of reported illness in the model, the function of bacterial density (p=0.7748).

The same comments apply to the risks involved for the factors included in this model, as for the previous model.

The model for overall illness versus P. aeruginosa (on mPA medium) is presented in Table 7.6. The factors included in this model, similar to all previous models, were:

Table 7.4 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus Enterococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.714	0.191	0.0001 (0.0001)	n.a.	n.a.
Entwetb	1	-0.049	0.054	0.3664 (0.3664)	0.95	0.86, 1.06
Newcp	1	0.426	0.054	0.0001 (0.0001)	2.34	1.90, 2.90
Newsba	1	0.143	0.046	0.0020 (0.0020)	1.33	1.11, 1.59
Age	1	-0.027	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.037	0.152	0.8090	n.a.	n.a., n.a.
Beach2	1	0.239	0.114	0.0353	n.a.	n.a., n.a.
Beach3	1	0.156	0.101	0.1237	n.a.	n.a., n.a.
Beach4	1	0.433	0.121	0.0003	n.a.	n.a., n.a.
Beach5	1	-0.326	0.206	0.1131 (0.0001)	n.a.	n.a., n.a.
Interv1	1	-0.316	0.512	0.5371	n.a.	n.a., n.a.
Interv2	1	0.892	0.303	0.0032	n.a.	n.a., n.a.
Interv3	1	0.777	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.102	0.192	0.5960	n.a.	n.a., n.a.
Interv5	1	-0.762	0.404	0.0591	n.a.	n.a., n.a.
Interv6	1	0.479	0.168	0.0043	n.a.	n.a., n.a.
Interv7	1	-0.201	0.168	0.2323	n.a.	n.a., n.a.
Interv8	1	0.695	0.167	0.0001	n.a.	n.a., n.a.
Interv9	1	0.667	0.159	0.0001	n.a.	n.a., n.a.
Interv10	1	-1.347	0.940	0.1520	n.a.	n.a., n.a.
Interv11	1	-1.019	0.688	0.1381	n.a.	n.a., n.a.
Interv12	1	-0.316	0.220	0.1515	n.a.	n.a., n.a.
Interv13	1	0.606	0.173	0.0004 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.104	0.045	0.0226 (0.0226)	0.81	0.68, 0.97
Wadeswim	1	0.036	0.161	0.8214	2.34	1.16, 4.70
	1	0.777	0.154	0.0001 (0.0001)	4.90	2.48, 9.69

Table 7.5 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus Fecal Streptococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	−2.742	0.217	0.0001 (0.0001)	n.a.	n.a.
Strwetb	1	−0.020	0.069	0.7748 (0.7748)	0.98	0.86, 1.12
Newcp	1	0.426	0.054	0.0001 (0.0001)	2.34	1.90, 2.90
Newsba	1	0.142	0.046	0.0021 (0.0021)	1.33	1.11, 1.59
Age	1	−0.027	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	−0.061	0.167	0.7139	n.a.	n.a., n.a.
Beach2	1	0.224	0.114	0.0489	n.a.	n.a., n.a.
Beach3	1	0.185	0.100	0.0627	n.a.	n.a., n.a.
Beach4	1	0.451	0.119	0.0002	n.a.	n.a., n.a.
Beach5	1	−0.341	0.205	0.0967 (0.0001)	n.a.	n.a., n.a.
Interv1	1	−0.215	0.499	0.6660	n.a.	n.a., n.a.
Interv2	1	0.870	0.303	0.0041	n.a.	n.a., n.a.
Interv3	1	0.764	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.086	0.192	0.6534	n.a.	n.a., n.a.
Interv5	1	−0.772	0.404	0.0588	n.a.	n.a., n.a.
Interv6	1	0.474	0.169	0.0050	n.a.	n.a., n.a.
Interv7	1	−0.218	0.167	0.1915	n.a.	n.a., n.a.
Interv8	1	0.679	0.169	0.0001	n.a.	n.a., n.a.
Interv9	1	0.640	0.157	0.0001	n.a.	n.a., n.a.
Interv10	1	−1.365	0.941	0.1467	n.a.	n.a., n.a.
Interv11	1	−0.926	0.679	0.1724	n.a.	n.a., n.a.
Interv12	1	−0.332	0.221	0.1328	n.a.	n.a., n.a.
Interv13	1	0.589	0.172	0.0006 (0.0001)	n.a.	n.a., n.a.
Sex	1	−0.104	0.045	0.0226 (0.0226)	0.81	0.68, 0.97
Wadeswim1	1	0.048	0.164	0.7707	2.28	1.06, 4.92
Wadeswim2	1	0.730	0.214	0.0007 (0.0007)	4.52	1.84, 11.09

Table 7.6 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus P. aeruginosa (on mPA)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.883	0.186	0.0001 (0.0001)	n.a.	n.a.
Pamwetb	1	0.097	0.049	0.0496 (0.0496)	1.10	1.00, 1.21
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.143	0.046	0.0021 (0.0021)	1.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.160	0.148	0.2776	n.a.	n.a. n.a.
Beach2	1	0.197	0.112	0.0785	n.a.	n.a. n.a.
Beach3	1	0.319	0.111	0.0041	n.a.	n.a. n.a.
Beach4	1	0.481	0.121	0.0001	n.a.	n.a. n.a.
Beach5	1	-0.469	0.216	0.0298 (0.0001)	n.a.	n.a. n.a.
Interv1	1	-0.096	0.497	0.5473	n.a.	n.a., n.a.
Interv2	1	0.977	0.307	0.0015	n.a.	n.a., n.a.
Interv3	1	0.724	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.097	0.192	0.6132	n.a.	n.a., n.a.
Interv5	1	-0.741	0.404	0.0665	n.a.	n.a., n.a.
Interv6	1	0.430	0.169	0.0106	n.a.	n.a., n.a.
Interv7	1	-0.201	0.168	0.2310	n.a.	n.a., n.a.
Interv8	1	0.581	0.171	0.0007	n.a.	n.a., n.a.
Interv9	1	0.592	0.157	0.0002	n.a.	n.a., n.a.
Interv10	1	-1.459	0.941	0.1211	n.a.	n.a., n.a.
Interv11	1	-0.823	0.678	0.2245	n.a.	n.a., n.a.
Interv12	1	-0.335	0.219	0.1261	n.a.	n.a., n.a.
Interv13	1	0.585	0.172	0.0006 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.105	0.045	0.0207 (0.0207)	0.81	0.68, 0.97
Wadeswim1	1	0.089	0.160	0.5766	2.07	1.06, 4.06
Wadeswim2	1	0.550	0.126	0.0001 (0.0001)	3.28	1.83, 5.89

contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), wadeswim (p=0.0001), swimming before or after (p=0.0021), sex (p=0.0207), and the function of the bacterial density (p=0.0496), all of which were important in the prediction of reported illness. Interestingly, in this particular model, the function of bacterial density attained baseline significance at the 5% level, unlike previous models.

Similar comments may be made about the risks associated with specific factors, as measured by the odds ratio data, as for the previous models, except that the risk of illness associated with swimmers was not as high as in many of the previous models.

For the model in which overall illness is considered versus P. aeruginosa (on mTIN; Table 7.7), the factors which were included were the same as for all the previous models; that is: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), wadeswim (p=0.0001), swimming before or after (p=0.0021), sex (p=0.0217), and the only factor for which there was no evidence that it contributed to the prediction of reported illness in the model - the function of bacterial count (p=0.2380).

The same comments hold true for the risks associated with the various factors included in the model as for the previous model.

In summary, the order from best to worst p-value for the function of bacterial density in the overall illness

Table 7.7 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus P. aeruginosa (on mTIN)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-0.283	0.184	0.0001 (0.0001)	n.a.	n.a.
Patwetb	1	0.069	0.058	0.2380 (0.2380)	1.07	0.96, 1.20
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.142	0.046	0.0021 (0.0021)	1.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.098	0.143	0.4937	n.a.	n.a., n.a.
Beach2	1	0.189	0.113	0.0950	n.a.	n.a., n.a.
Beach3	1	0.233	0.097	0.0159	n.a.	n.a., n.a.
Beach4	1	0.462	0.120	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.405	0.213	0.0578 (0.0001)	n.a.	n.a., n.a.
Interv1	1	-0.164	0.495	0.7413	n.a.	n.a., n.a.
Interv2	1	0.917	0.304	0.0026	n.a.	n.a., n.a.
Interv3	1	0.755	0.174	0.0001	n.a.	n.a., n.a.
Interv4	1	0.077	0.191	0.6865	n.a.	n.a., n.a.
Interv5	1	-0.786	0.404	0.0515	n.a.	n.a., n.a.
Interv6	1	0.468	0.167	0.0052	n.a.	n.a., n.a.
Interv7	1	-0.224	0.167	0.1799	n.a.	n.a., n.a.
Interv8	1	0.632	0.168	0.0002	n.a.	n.a., n.a.
Interv9	1	0.614	0.157	0.0001	n.a.	n.a., n.a.
Interv10	1	-1.345	0.940	0.1523	n.a.	n.a., n.a.
Interv11	1	-0.881	0.677	0.1931	n.a.	n.a., n.a.
Interv12	1	-0.338	0.219	0.1229	n.a.	n.a., n.a.
Interv13	1	0.567	0.172	0.0010 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.104	0.045	0.0217 (0.0217)	0.81	0.68, 0.97
Wadeswim1	1	0.076	0.160	0.6326	2.12	1.08, 4.16
Wadeswim2	1	0.599	0.127	0.0001 (0.0001)	3.58	1.99, 6.44

models was: *P. aeruginosa* on mPA (p=0.0496), *P. aeruginosa* on mTIN (p=0.2380), *E. coli* (p=0.3243), the enterococci (p=0.3664), fecal coliforms (p=0.5109), the total staphylococci (p=0.7224), and the fecal streptococci (p=0.7748). It should be noted that the standard errors of the estimates frequently overlap. Apart from *P. aeruginosa* on mPA, there was no evidence that the function of the bacterial density contributed to the prediction of reported overall illness, and even *P. aeruginosa* on mPA achieved only marginal importance. Interestingly, the estimates were negative for the functions of the fecal streptococci, fecal coliforms, the enterococci, and *E. coli*, but no significance could be attached to this.

Referring back to Table 5.10, it will be obvious that the odds ratios associated with illness in swimmers (O.R. 4.23, 95%c.l. 2.77, 6.46), for the crude data, were not greatly different from the odds ratios generated by logistic regression modelling. The same comments may be applied to waders (crude O.R.=2.22, 95%c.l. 24, 3.97), as well. In general, both swimmers and waders were at significantly elevated risk of becoming ill when they were compared to persons who did not go into the water, and the risk was greater for swimmers than for waders.

7.4.2 Example of alteration of function of bacterial count in the model for overall illness versus *P. aeruginosa*

In order to evaluate the influence of multiplying the

natural logarithm of the geometric mean of the bacterial density by a factor of 0.3 in waders, models were generated in which the factor was changed to 0.5 (Table 7.8), 0.7 (Table 7.9), and 0.9 (Table 7.10). It is clear that no extreme differences resulted in the factors included in the models, the estimates, or the risks (odds ratios) involved. However, in the latter two models, unlike the first model and the model in Table 7.6, waders were not at significantly increased risk of becoming ill, such that it may be wise to keep this in mind. Thus, issue could sometimes be taken with the risk for waders, particularly in borderline cases. It will be shown that no major difference was observed in the gastrointestinal (GI) models outlined in the next section.

7.4.3 Gastrointestinal (GI) illness models

In Table 7.11, the model for GI illness versus fecal coliforms is presented. The factors included in the model were: interviewer (p=0.0001), age (p=0.0001), contact person (p=0.0133), swimming before or after the interview day (p=0.0729), the function of the fecal coliform count (p=0.0867), and wadeswim (p=0.3572). There was no evidence that the last factor was important to the model. The fourth and fifth factors were included for reasons presented in Section 7.2.

From the odds ratio data, it is apparent that contact persons were at significantly increased risk of GI illness

Table 7.8 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus P. aeruginosa (on mPA)
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.5)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.894	0.1889	0.0001 (0.0001)	n.a.	n.a.
Pamwetc	1	0.095	0.049	0.0544 (0.0544)	1.10	1.00, 1.21
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.143	0.046	0.0021 (0.0021)	1.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.159	0.148	0.2821	n.a.	n.a., n.a.
Beach2	1	0.197	0.112	0.0780	n.a.	n.a., n.a.
Beach3	1	0.318	0.112	0.0044	n.a.	n.a., n.a.
Beach4	1	0.481	0.121	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.469	0.216	0.0302 (0.0302)	n.a.	n.a., n.a.
Interv1	1	-0.099	0.497	0.8426	n.a.	n.a., n.a.
Interv2	1	0.978	0.307	0.0015	n.a.	n.a., n.a.
Interv3	1	0.725	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.096	0.192	0.6148	n.a.	n.a., n.a.
Interv5	1	-0.742	0.404	0.0663	n.a.	n.a., n.a.
Interv6	1	0.431	0.169	0.0105	n.a.	n.a., n.a.
Interv7	1	-0.201	0.168	0.2293	n.a.	n.a., n.a.
Interv8	1	0.581	0.171	0.0007	n.a.	n.a., n.a.
Interv9	1	0.593	0.157	0.0002	n.a.	n.a., n.a.
Interv10	1	-1.458	0.941	0.1214	n.a.	n.a., n.a.
Interv11	1	-0.823	0.678	0.2247	n.a.	n.a., n.a.
Interv12	1	-0.335	0.219	0.1262	n.a.	n.a., n.a.
Interv13	1	0.585	0.172	0.0006 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.105	0.045	0.0208 (0.0208)	0.81	0.68, 0.97
Wadeswim	1	0.062	0.159	0.6954	1.99	1.02, 3.89
	1	0.566	0.123	0.0001 (0.0001)	3.30	1.86, 5.86

Table 7.9 Effect of Selected Variables on Risk of Illness (n=8420 people)

Model: Overall Illness versus P. aeruginosa (on mPA)
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.7)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.904	0.190	0.0001 (0.0001)	n.a.	n.a.
Pamwetd	1	0.092	0.049	0.0607 (0.0607)	1.10	1.00, 1.21
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.143	0.046	0.0021 (0.0021)	1.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.157	0.148	0.2884	n.a.	n.a., n.a.
Beach2	1	0.198	0.112	0.0772	n.a.	n.a., n.a.
Beach3	1	0.315	0.112	0.0047	n.a.	n.a., n.a.
Beach4	1	0.481	0.121	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.468	0.216	0.0309 (0.0301)	n.a.	n.a., n.a.
Interv1	1	-0.102	0.497	0.8367	n.a.	n.a., n.a.
Interv2	1	0.979	0.308	0.0015	n.a.	n.a., n.a.
Interv3	1	0.726	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.096	0.192	0.6168	n.a.	n.a., n.a.
Interv5	1	-0.742	0.404	0.0660	n.a.	n.a., n.a.
Interv6	1	0.432	0.169	0.0104	n.a.	n.a., n.a.
Interv7	1	-0.202	0.167	0.2272	n.a.	n.a., n.a.
Interv8	1	0.583	0.171	0.0007	n.a.	n.a., n.a.
Interv9	1	0.594	0.157	0.0002	n.a.	n.a., n.a.
Interv10	1	-1.456	0.941	0.1219	n.a.	n.a., n.a.
Interv11	1	-0.823	0.678	0.2245	n.a.	n.a., n.a.
Interv12	1	-0.335	0.219	0.1262	n.a.	n.a., n.a.
Interv13	1	0.585	0.172	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.105	0.045	0.0210 (0.0210)	0.81	0.68, 0.97
Wadeswim	1	0.036	0.160	0.8206	1.92	0.98, 3.76
	1	0.582	0.119	0.0001 (0.0001)	3.32	1.89, 5.82

Table 7.10 Effect of Selected Variables on Risk of Illness

Model: Overall Illness versus P. aeruginosa (on mPA)
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.9)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.912	0.193	0.0001 (0.0001)	n.a.	n.a.
Pamwete	1	0.089	0.049	0.0685 (0.0685)	1.09	0.99, 1.20
Newcp	1	0.425	0.054	0.0001 (0.0001)	2.34	1.89, 2.89
Newsba	1	0.142	0.046	0.0021 (0.0021)	0.33	1.11, 1.59
Age	1	-0.028	0.004	0.0001 (0.0001)	0.97	0.96, 0.98
Beach1	1	-0.154	0.147	0.2961	n.a.	n.a., n.a.
Beach2	1	0.198	0.112	0.0762	n.a.	n.a., n.a.
Beach3	1	0.312	0.112	0.0052	n.a.	n.a., n.a.
Beach4	1	0.480	0.121	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.465	0.217	0.0319 (0.0001)	n.a.	n.a., n.a.
Interv1	1	-0.107	0.497	0.8299	n.a.	n.a., n.a.
Interv2	1	0.979	0.308	0.0015	n.a.	n.a., n.a.
Interv3	1	0.727	0.175	0.0001	n.a.	n.a., n.a.
Interv4	1	0.095	0.192	0.6191	n.a.	n.a., n.a.
Interv5	1	-0.743	0.404	0.0656	n.a.	n.a., n.a.
Interv6	1	0.433	0.169	0.0102	n.a.	n.a., n.a.
Interv7	1	-0.203	0.167	0.2249	n.a.	n.a., n.a.
Interv8	1	0.585	0.171	0.0006	n.a.	n.a., n.a.
Interv9	1	0.595	0.157	0.0002	n.a.	n.a., n.a.
Interv10	1	-1.454	0.941	0.1226	n.a.	n.a., n.a.
Interv11	1	-0.825	0.678	0.2237	n.a.	n.a., n.a.
Interv12	1	-0.335	0.219	0.1263	n.a.	n.a., n.a.
Interv13	1	0.584	0.171	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.105	0.045	0.0212 (0.0212)	0.81	0.68, 0.97
Wadeswim	1	0.011	0.161	0.9428	1.86	0.95 3.64
	1	0.598	0.116	0.0001 (0.0001)	3.34	1.92, 5.82

Table 7.11 Effect of Selected Variables on Risk of Gastrointestinal (GI) Illness (n=8420 people)

Model: GI Illness versus Fecal Coliforms						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95% c.l.
Intercept	1	-5.427	5.167	0.2935 (0.2935)	n.a.	n.a.
Fecwetb	1	0.150	0.087	0.0867 (0.0867)	1.16	0.98, 1.38
Newcp	1	0.251	0.101	0.0133 (0.0133)	1.65	1.11, 2.45
Newsba	1	0.149	0.083	0.0729 (0.0729)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.98	0.96, 0.99
Interv1	1	1.056	5.242	0.8403	n.a.	n.a., n.a.
Interv2	1	2.869	5.169	0.5789	n.a.	n.a., n.a.
Interv3	1	1.720	5.163	0.7390	n.a.	n.a., n.a.
Interv4	1	0.555	5.168	0.9145	n.a.	n.a., n.a.
Interv5	1	-0.005	5.241	0.9992	n.a.	n.a., n.a.
Interv6	1	1.417	5.163	0.7838	n.a.	n.a., n.a.
Interv7	1	0.372	5.163	0.9426	n.a.	n.a., n.a.
Interv8	1	1.749	5.162	0.7348	n.a.	n.a., n.a.
Interv9	1	1.881	5.160	0.7155	n.a.	n.a., n.a.
Interv10	1	-7.724	49.917	0.8870	n.a.	n.a., n.a.
Interv11	1	-7.708	45.026	0.8641	n.a.	n.a., n.a.
Interv12	1	1.040	5.167	0.8406	n.a.	n.a., n.a.
Interv13	1	1.731	5.161	0.7373 (0.001)	n.a.	n.a., n.a.
Wadeswim1	1	0.365	0.277	0.1874	2.23	0.61, 8.21
Wadeswim2	1	0.072	0.368	0.8446 (0.3572)	1.66	0.36, 7.77

in contrast to persons who were not contact persons. The function of bacterial count had little effect on risk. Swimming before or after the interview day carried slightly increased risk of GI illness, but was not significant. Younger persons had greater odds of contracting GI illness than older persons. Waders were at increased risk of GI illness, but this was not significant, and swimmers were not at significantly increased risk of becoming ill. Although the risks associated with water exposure seemed to be reversed, such that the waders seemed to be at higher risk than the swimmers, the trend was not significant.

The model for GI illness versus E. coli appears in Table 7.12. In this model, the factors which were included were: interviewer ($p=0.0001$), age ($p=0.0001$), contact person ($p=0.0132$), swimming before or after the interview day ($p=0.0708$), the function of the E. coli count ($p=0.0885$), and wadeswim ($p=0.3524$). There was no evidence that the function of the bacterial count contributed to the prediction of reported GI illness, and the same can be said for the classification of water exposure (i.e: wadeswim).

The risk of GI illness appeared to be significantly higher in contact persons. Younger persons had greater odds of becoming ill than did older persons. Swimming before or after the interview day put people at slightly, but not significantly, increased risk over those who did not do this. The function of bacterial density had little effect on the risk of reported GI illness. Comments concerning the waders and swimmers were the same as for the previous

Table 7.12 Effect of Selected Variables on Risk of GI Illness (n=8420 people)

Model: GI Illness versus *E. coli*						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.411	5.166	0.2949 (0.2949)	n.a.	n.a.
Ecwetb	1	0.145	0.085	0.0885 (0.0885)	1.16	0.97, 1.37
Newcp	1	0.251	0.101	0.0132 (0.0132)	1.65	1.11, 2.45
Newsba	1	0.150	0.083	0.0708 (0.0708)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.97	0.96, 0.99
Interv1	1	1.037	5.241	0.8432	n.a.	n.a., n.a.
Interv2	1	2.878	5.168	0.5776	n.a.	n.a., n.a.
Interv3	1	1.716	5.162	0.7396	n.a.	n.a., n.a.
Interv4	1	0.559	5.167	0.9138	n.a.	n.a., n.a.
Interv5	1	-0.013	5.240	0.9980	n.a.	n.a., n.a.
Interv6	1	1.413	5.162	0.7843	n.a.	n.a., n.a.
Interv7	1	0.377	5.162	0.9417	n.a.	n.a., n.a.
Interv8	1	1.752	5.161	0.7342	n.a.	n.a., n.a.
Interv9	1	1.893	5.159	0.7136	n.a.	n.a., n.a.
Interv10	1	-7.728	49.917	0.8770	n.a.	n.a., n.a.
Interv11	1	-7.725	45.008	0.8637	n.a.	n.a., n.a.
Interv12	1	1.059	5.166	0.8375	n.a.	n.a., n.a.
Interv13	1	1.734	5.160	0.7368 (0.0001)	n.a.	n.a., n.a.
Wadeswim1	1	0.358	0.276	0.1944	2.20	0.61, 7.96
Wadeswim2	1	0.072	0.355	0.8398 (0.3524)	1.65	0.37, 7.35

model.

For the GI illness versus the enterococci model in Table 7.13, the factors included in the model were: interviewer (p=0.0001), age (p=0.0004), contact person (p=0.0138), wadeswim (p=0.0252), swimming before or after the interview day (p=0.0716), sex (p=0.0964), and the function of the enterococcal density (p=0.9963). This model suggests that the final factor did not contribute significantly to the prediction of reported illness.

The odds ratios associated with this model showed that contact persons had a significantly increased risk of GI illness. Swimming before or after the interview day was associated with a slightly, but not significantly, increased risk. The same comments may be made for the risks associated with age, as for the previous model. Although males were at slightly reduced risk of becoming ill, the effect was not significant. The function of the enterococcal count had little effect on the risk of GI illness. Waders were at increased risk of becoming ill, but this was not significant, and swimmers displayed significantly increased risk of becoming ill.

The model for GI illness versus the fecal streptococci appears in Table 7.14. The factors included in the model were: interviewer (p=0.0001), age (p=0.0004), contact person (p=0.0137), wadeswim (p=0.0509), swimming before or after the interview day (p=0.0729), sex (p=0.0967), and the function of the fecal streptococcal density (p=0.9114).

Once more, there was no evidence to suggest that the

Table 7.13 Effect of Selected Variables on Risk of GI Illness (n=8420 people)

Model: GI Illness versus Enterococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.102	5.146	0.3215 (0.3215)	n.a.	n.a.
Entwetb	1	0.000	0.082	0.9963 (0.9963)	1.00	0.85, 1.17
Newcp	1	0.250	0.101	0.0138 (0.0138)	1.65	1.11, 2.45
Newsba	1	0.150	0.083	0.0716 (0.0716)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.97	0.96, 0.99
Interv1	1	0.894	0.523	0.8643	n.a.	n.a., n.a.
Interv2	1	2.880	5.151	0.5762	n.a.	n.a., n.a.
Interv3	1	1.791	5.145	0.7278	n.a.	n.a., n.a.
Interv4	1	0.557	5.151	0.9139	n.a.	n.a., n.a.
Interv5	1	-0.091	5.223	0.9861	n.a.	n.a., n.a.
Interv6	1	1.480	5.146	0.7736	n.a.	n.a., n.a.
Interv7	1	0.411	5.146	0.9364	n.a.	n.a., n.a.
Interv8	1	1.849	5.144	0.7193	n.a.	n.a., n.a.
Interv9	1	1.887	5.143	0.7137	n.a.	n.a., n.a.
Interv10	1	-7.808	49.805	0.8754	n.a.	n.a., n.a.
Interv11	1	-7.871	44.810	0.8606	n.a.	n.a., n.a.
Interv12	1	1.130	5.150	0.8263	n.a.	n.a., n.a.
Interv13	1	1.773	5.144	0.7304 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.136	0.082	0.0964 (0.0964)	0.76	0.55, 1.05
Wadeswim1	1	0.228	0.270	0.3993	2.84	0.88, 9.17
Wadeswim2	1	0.589	0.255	0.0208 (0.0252)	4.08	1.32, 12.64

Table 7.14 Effect of Selected Variables on Risk of GI Illness (n=8420 people)

Model: GI Illness versus Fecal Streptococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.085	5.147	0.3231 (0.3231)	n.a.	n.a.
Strwetb	1	-0.010	0.092	0.9114 (0.9114)	1.00	0.83, 1.19
Newcp	1	0.250	0.101	0.0137 (0.0137)	1.65	1.11, 2.45
Newsba	1	0.149	0.083	0.0729 (0.0729)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.97	0.96, 0.99
Interv1	1	0.880	5.224	0.8663	n.a.	n.a., n.a.
Interv2	1	2.878	5.150	0.5763	n.a.	n.a., n.a.
Interv3	1	1.794	5.144	0.7272	n.a.	n.a., n.a.
Interv4	1	0.558	5.149	0.9136	n.a.	n.a., n.a.
Interv5	1	-0.095	5.222	0.9855	n.a.	n.a., n.a.
Interv6	1	1.486	5.145	0.7728	n.a.	n.a., n.a.
Interv7	1	0.414	5.145	0.9359	n.a.	n.a., n.a.
Interv8	1	1.858	5.144	0.7179	n.a.	n.a., n.a.
Interv9	1	1.888	5.141	0.7135	n.a.	n.a., n.a.
Interv10	1	-7.817	49.797	0.8753	n.a.	n.a., n.a.
Interv11	1	-7.883	44.801	0.8603	n.a.	n.a., n.a.
Interv12	1	1.137	5.149	0.8252	n.a.	n.a., n.a.
Interv13	1	1.777	5.143	0.7297 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.136	0.082	0.0967 (0.0967)	0.76	0.55, 1.05
Wadeswim1	1	0.221	0.273	0.4185	2.88	0.84, 9.87
Wadeswim2	1	0.617	0.310	0.0463 (0.0509)	4.28	1.14, 16.16

function of the bacterial count contributed to the prediction of reported GI illness. Similar comments to the previous models may be made concerning the risks of illness associated with age. Males were at slightly, but not significantly, reduced risk of contracting GI illness. The function of bacterial count, had little effect on the risk of GI illness. Swimming before or after was identified as a factor associated with a slightly elevated risk of GI illness (versus those who did not swim before or after), but it was not significant. Contact persons were at significantly increased risk of GI illness in contrast to non-contact persons. Waders were at increased risk of GI illness, but this was not a significant increase. Swimmers were at significantly elevated risk of contracting GI illness.

Examination of the GI illness models reveals that for the function of bacterial density, the order from the best to worst chi-square p-value was: fecal coliforms (p=0.0867), E. coli (p=0.0855), the fecal streptococci (p=0.9114; but the estimate was slightly negative), and the enterococci (p=0.9963). The standard errors of these estimates frequently overlap. The function of the bacterial count may not significantly affect the prediction of reported GI illness.

If one refers back to Table 5.10, it is clear that the odds ratios associated with GI illness in swimmers (O.R.=4.38, 95%c.l. 1.93, 9.93) and waders (O.R.=3.15 95%c.l. 1.12, 8.90) for the crude data, varied somewhat

from those presented in this section. In these models, half of them indicate that swimmers, and waders were at significantly increased risk of GI illness, and half of them indicate that, swimmers, but not waders, were at increased risk. It seems apparent that the models in which swimmers were at significantly elevated risk had much less emphasis on the function of bacterial density, whereas in the others it played a more prominent role. Evidently, some sort of interaction existed between the function of the bacterial density and wadeswim, despite the fact that the function of bacterial density took water exposure into account. It may also be prudent to remember that GI illness, or any specific illness category other than overall illness, contained far fewer ill persons than the overall illness category contained.

7.4.4 Example of alteration of the function of bacterial count in the model for gastrointestinal illness versus fecal coliforms

Refering to Tables 7.15 to 7.17, the effect of altering the function of bacterial count for the waders is investigated for GI illness versus fecal coliforms. The natural logarithm of the bacterial count was multiplied by 0.5, 0.7, and 0.9 for the wading population. Once again it was clear that no extreme difference existed between these models and those presented using a factor of 0.3, but the risk of illness associated with waders was somewhat reduced

Table 7.15 Effect of Selected Variables on Risk of Gastroinestinal (GI) Illness (n=8420)

Model: GI Illness versus Fecal Coliforms
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.5)

Variables	df	Estimate	S.E.	p-value estimate (p-value overall)	O.R.	95%c.l.
Intercept	1	-5.487	5.169	0.2883 (0.2883)	n.a.	n.a.
Fecwetc	1	0.149	0.087	0.0868 (0.0868)	1.16	0.98, 1.38
Newcp	1	0.251	0.101	0.0132 (0.0132)	1.65	1.11, 2.45
Newsba	1	0.149	0.083	0.0729 (0.0729)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.97	0.99, 1.36
Interv1	1	1.055	5.242	0.8405	n.a.	n.a., n.a.
Interv2	1	2.870	5.168	0.5787	n.a.	n.a., n.a.
Interv3	1	1.719	5.162	0.7391	n.a.	n.a., n.a.
Interv4	1	0.555	5.167	0.9145	n.a.	n.a., n.a.
Interv5	1	-0.005	5.240	0.9992	n.a.	n.a., n.a.
Interv6	1	1.416	5.162	0.7838	n.a.	n.a., n.a.
Interv7	1	0.371	5.162	0.9427	n.a.	n.a., n.a.
Interv8	1	1.748	5.161	0.7348	n.a.	n.a., n.a.
Interv9	1	1.881	5.159	0.7154	n.a.	n.a., n.a.
Interv10	1	-7.722	49.911	0.8770	n.a.	n.a., n.a.
Interv11	1	-7.705	45.018	0.8641	n.a.	n.a., n.a.
Interv12	1	1.039	5.166	0.8406	n.a.	n.a., n.a.
Interv13	1	1.731	5.161	0.7374 (0.0001)	n.a.	n.a., n.a.
Wadeswim	1	0.240	0.267	0.3686	1.80	0.52, 6.20
	1	0.108	0.336	0.7489 (0.6123)	1.58	0.38, 6.51

Table 7.16 Effect of Selected Variables on Risk of Gastroinestinal (GI) Illness (n=8420)

Model: GI Illness versus Fecal Coliforms
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.7)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.546	5.168	0.2833 (0.2833)	n.a.	n.a.
Fecwetd	1	0.148	0.087	0.0875 (0.0875)	1.16	0.98, 1.38
Newcp	1	0.251	0.101	0.0131 (0.0131)	1.65	1.11, 2.45
Newsba	1	0.149	0.083	0.0728 (0.0728)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0004 (0.0004)	0.97	0.99, 1.36
Interv1	1	1.053	5.241	0.8407	n.a.	n.a., n.a.
Interv2	1	2.871	5.167	0.5785	n.a.	n.a., n.a.
Interv3	1	1.719	5.161	0.7391	n.a.	n.a., n.a.
Interv4	1	0.554	5.166	0.9145	n.a.	n.a., n.a.
Interv5	1	-0.006	5.239	0.9991	n.a.	n.a., n.a.
Interv6	1	1.416	5.161	0.7838	n.a.	n.a., n.a.
Interv7	1	0.371	5.160	0.9428	n.a.	n.a., n.a.
Interv8	1	1.748	5.160	0.7349	n.a.	n.a., n.a.
Interv9	1	1.881	5.158	0.7153	n.a.	n.a., n.a.
Interv10	1	-7.721	49.905	0.8770	n.a.	n.a., n.a.
Interv11	1	-7.702	45.009	0.8641	n.a.	n.a., n.a.
Interv12	1	1.039	5.165	0.8406	n.a.	n.a., n.a.
Interv13	1	1.730	5.160	0.7374 (0.0001)	n.a.	n.a., n.a.
Wadeswim	1	0.115	0.276	0.6761	1.50	0.43, 5.16
	1	0.173	0.306	0.5704 (0.7967)	1.59	0.43, 5.91

Table 7.17 Effect of Selected Variables on Risk of Gastroinestinal (GI) Illness (n=8420)

Model: GI Illness versus Fecal Coliforms
(Note that for waders, the $\log_e$ bacterial count is multiplied by 0.9)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.601	5.169	0.2786 (0.2786)	n.a.	n.a.
Fecwete	1	0.146	0.086	0.0888 (0.0888)	1.16	0.98, 1.38
Newcp	1	0.252	0.101	0.0131 (0.0131)	1.66	1.11, 2.46
Newsba	1	0.149	0.083	0.0728 (0.0728)	1.35	0.97, 1.87
Age	1	-0.027	0.008	0.0003 (0.0003)	0.97	0.99, 1.36
Interv1	1	1.051	5.240	0.8411	n.a.	n.a., n.a.
Interv2	1	2.872	5.166	0.5782	n.a.	n.a., n.a.
Interv3	1	1.719	5.160	0.7390	n.a.	n.a., n.a.
Interv4	1	0.554	5.165	0.9146	n.a.	n.a., n.a.
Interv5	1	-0.007	5.238	0.9990	n.a.	n.a., n.a.
Interv6	1	1.416	5.161	0.7838	n.a.	n.a., n.a.
Interv7	1	0.371	5.160	0.9428	n.a.	n.a., n.a.
Interv8	1	1.881	5.157	0.7153	n.a.	n.a., n.a.
Interv9	1	1.881	5.157	0.7153	n.a.	n.a., n.a.
Interv10	1	-7.720	49.898	0.8770	n.a.	n.a., n.a.
Interv11	1	-7.701	44.998	0.8641	n.a.	n.a., n.a.
Interv12	1	1.039	5.164	0.8406	n.a.	n.a., n.a.
Interv13	1	1.730	5.159	0.7373 (0.0001)	n.a.	n.a., n.a.
Wadeswim	1	0.007	0.304	0.9828	1.29	0.35, 4.78
	1	0.240	0.277	0.3862 (0.6683)	1.63	0.47, 5.62

in these models, and the directions of the risks were more plausible in the latter two models. However, the risk of illnes for waders was not significant in any of these models.

7.4.5 Models for ear problems

The model for ear problems versus P. aeruginosa on mPA is presented in Table 7.18. The factors which were incorporated into this model were: contact person ($p=0.0001$), age ($p=0.0082$), wadeswim ($p=0.0535$), beach ($p=0.1072$), interviewer ($p=0.1611$), and the function of bacterial count ($p=0.7502$). There was no evidence to suggest that the function of bacterial count contributed to the prediction of ear problems.

In this model, function of bacterial count had little effect on the risk of ear problems. Younger persons had greater odds of becoming ill than older persons. Contact persons were at significantly elevated risk of becoming afflicted in contrast to persons who were not contact persons. Waders were at elevated, but not significantly elevated, risk of becoming afflicted, whereas swimmers were at significantly elevated risk.

Examination of Table 7.19 shows the model constructed for ear problems versus P. aeruginosa on mTIN. The following factors were incorporated into the model: contact person ($p=0.0001$), age ($p=0.0093$), wadeswim ($p=0.0251$), sex ($p=0.0822$), interviewer ($p=0.1223$), and the function of

Table 7.18 Effect of Selected Variables on Risk of Ear Problems in Swimmers (n=8420 people)

Model: Ear Problems versus P. aeruginosa (on mPA)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-6.311	7.912	0.4251 (0.4251)	n.a.	n.a.
Pamwetb	1	-0.041	0.128	0.7502 (0.7502)	0.96	0.75, 1.23
Newcp	1	0.632	0.143	0.0001 (0.0001)	2.90	1.65, 5.08
Age	1	-0.031	0.012	0.0082 (0.0082)	0.97	0.95, 0.99
Beach1	1	-0.310	0.475	0.5136	n.a.	n.a., n.a.
Beach2	1	0.451	0.304	0.1383	n.a.	n.a., n.a.
Beach3	1	0.328	0.304	0.2801	n.a.	n.a., n.a.
Beach4	1	0.639	0.318	0.0443	n.a.	n.a., n.a.
Beach5	1	0.159	0.540	0.7685 (0.1072)	n.a.	n.a., n.a.
Interv1	1	-8.105	72.517	0.9110	n.a.	n.a., n.a.
Interv2	1	2.044	7.934	0.7967	n.a.	n.a., n.a.
Interv3	1	1.779	7.910	0.8220	n.a.	n.a., n.a.
Interv4	1	1.743	7.910	0.8256	n.a.	n.a., n.a.
Interv5	1	0.813	7.956	0.9186	n.a.	n.a., n.a.
Interv6	1	1.784	7.907	0.8215	n.a.	n.a., n.a.
Interv7	1	1.330	7.908	0.8665	n.a.	n.a., n.a.
Interv8	1	2.420	7.906	0.7975	n.a.	n.a., n.a.
Interv9	1	2.029	7.906	0.7975	n.a.	n.a., n.a.
Interv10	1	2.074	7.958	0.7944	n.a.	n.a., n.a.
Interv11	1	-7.997	73.119	0.9129	n.a.	n.a., n.a.
Interv12	1	-0.288	7.955	0.9910	n.a.	n.a., n.a.
Interv13	1	-0.081	7.955	0.9919 (0.1611)	n.a.	n.a., n.a.
Wadeswim1	1	0.104	0.459	0.8207	2.90	0.42,20.17
Wadeswim2	1	0.857	0.369	0.0201 (0.0535)	6.16	1.12,33.83

Table 7.19 Effect of Selected Variables on Risk of Ear Problems (n=8420 people)

Model: Ear Problems versus P. aeruginosa (on mTIN)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-6.335	7.8949	0.4223 (0.4223)	n.a.	n.a.
Patwetb	1	-0.123	0.155	0.4296 (0.4296)	0.88	0.65, 1.20
Newcp	1	0.632	0.143	0.0001 (0.0001)	3.54	2.02, 6.20
Age	1	-0.031	0.012	0.0093 (0.0001)	0.97	0.95, 0.99
Beach1	1	-0.319	0.467	0.4943	n.a.	n.a., n.a.
Beach2	1	0.485	0.313	0.1211	n.a.	n.a., n.a.
Beach3	1	0.322	0.272	0.2357	n.a.	n.a., n.a.
Beach4	1	0.652	0.318	0.0399	n.a.	n.a., n.a.
Beach5	1	0.204	0.525	0.6971 (0.0822)	n.a.	n.a., n.a.
Interv1	1	-8.086	72.433	0.9111	n.a.	n.a., n.a.
Interv2	1	2.003	7.915	0.8003	n.a.	n.a., n.a.
Interv3	1	1.770	7.891	0.8225	n.a.	n.a., n.a.
Interv4	1	1.700	7.893	0.8294	n.a.	n.a., n.a.
Interv5	1	0.861	7.938	0.9136	n.a.	n.a., n.a.
Interv6	1	1.787	7.889	0.8208	n.a.	n.a., n.a.
Interv7	1	1.332	7.890	0.8660	n.a.	n.a., n.a.
Interv8	1	2.479	7.888	0.7533	n.a.	n.a., n.a.
Interv9	1	2.066	7.888	0.7933	n.a.	n.a., n.a.
Interv10	1	1.993	7.939	0.8018	n.a.	n.a., n.a.
Interv11	1	-8.019	72.871	0.9124	n.a.	n.a., n.a.
Interv12	1	-0.275	7.937	0.9723	n.a.	n.a., n.a.
Interv13	1	-0.064	7.937	0.9936 (0.1223)	n.a.	n.a., n.a.
Sex	1	-0.234	0.127	0.0650 (0.0650)	0.63	0.38, 1.03
Wadeswim	1	0.059	0.460	0.8973	2.98	0.43,20.82
	1	0.975	0.369	0.0083 (0.0251)	7.46	1.36,41.00

bacterial count (p=0.4296). There was no evidence that the function of the bacterial count contributed to the prediction of reported ear ailments. The comments made about the odds ratios in the previous model also apply to this model, although males had a decreased, but non-significant, risk of contracting ear problems.

In the two previous models, the best to worst chi-square p-values for the function of bacterial count were: P. aeruginosa on mTIN (p=0.4296), and P. aeruginosa on mPA (p=0.7502), but the estimates associated with the functions of count were negative, whilst the standard errors of the estimates overlap. There was no evidence to suggest that the function of the bacterial count contributed to the prediction of reported ear ailments, despite the fact that this organism is considered to be pathogenic in such cases (Buchanan and Gibbons, 1974).

Table 5.10 shows that for the crude data the odds ratios associated with swimmers was 5.78 (95%c.l. 1.41, 23.66), and for waders was 3.13 (95%c.l. 0.52, 18.78). Thus, the crude odds ratios varied somewhat from those presented in this section and yet the overall deductions remain the same. For ear problems, waders were not at elevated risk, in contrast to swimmers for whom the risks were significantly elevated.

7.4.6 Skin, respiratory, and eye problems

The model generated for skin problems versus the total

staphylococci is presented in Table 7.20. The factors which were included in the model were: interviewer (p=0.0007), contact person (p=0.0086), age (p=0.014), function of the total staphylococcal count (p=0.0564), and wadeswim (p=0.8352). There was no evidence to suggest that the function of the total staphylococcal count contributed to the prediction of reported skin problems.

Age and the function of the total staphylococcal count had little effect on the risk of skin problems. Contact persons were associated with significantly elevated risks. Waders seemed to be at reduced risk of contracting skin problems, but this finding was not statistically significant. For swimmers, the risk of skin problems was slightly reduced, but not statistically significant.

The crude odds ratios in Table 5.10 indicate that swimmers (O.R.=3.37, 95%c.l. 1.05, 10.77) differed from that found herein, and the risk for waders (O.R.=0.69, 95%c.l. 0.07, 6.67) was similar.

In Table 7.21, the model for respiratory ailments versus the total staphylococci is shown. Included in this model were: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0002), wadeswim (p=0.0022), beach (p=0.0181), swimming before or after the interview day (p=0.0419), and the function of the bacterial count (p=0.1952; but the estimate was negative). For the last factor, there was no evidence that it contributed to the prediction of reported respiratory ailments.

The function of the total staphylococcal count had

Table 7.20 Effect of Selected Variables on Risk of Skin Problems (n=8420 people)

Model: Skin Problems versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-7.719	16.013	0.6298 (0.6298)	n.a.	n.a.
Stwetb	1	0.278	0.145	0.0564 (0.0564)	1.32	1.00, 1.75
Newcp	1	0.413	0.157	0.0086 (0.0086)	2.28	1.23, 4.23
Age	1	-0.031	0.013	0.014 (0.014)	0.97	0.95, 1.00
Interv1	1	2.901	16.032	0.8564	n.a.	n.a., n.a.
Interv2	1	-7.390	102.499	0.9425	n.a.	n.a., n.a.
Interv3	1	2.499	16.010	0.8759	n.a.	n.a., n.a.
Interv4	1	1.140	16.017	0.9433	n.a.	n.a., n.a.
Interv5	1	1.976	16.031	0.9019	n.a.	n.a., n.a.
Interv6	1	3.438	16.006	0.8299	n.a.	n.a., n.a.
Interv7	1	0.360	16.017	0.9821	n.a.	n.a., n.a.
Interv8	1	3.051	16.007	0.8488	n.a.	n.a., n.a.
Interv9	1	2.716	16.006	0.8653	n.a.	n.a., n.a.
Interv10	1	-7.730	135.131	0.9544	n.a.	n.a., n.a.
Interv11	1	-7.732	122.586	0.9497	n.a.	n.a., n.a.
Interv12	1	2.087	76.011	0.8963	n.a.	n.a., n.a.
Interv13	1	1.205	16.018	0.9400 (0.0007)	n.a.	n.a., n.a.
Wadeswim1	1	-0.357	0.708	0.6146	0.50	0.02, 10.20
Wadeswim2	1	0.011	0.615	0.9854 (0.8352)	0.72	0.04, 11.55

Table 7.21 Effect of Selected Variables on Risk of Respiratory Illness (n=8420 people)

Model: Respiratory Problems versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-4.515	5.060	0.3723 (0.3723)	n.a.	n.a.
Stwetb	1	-0.134	0.104	0.1952 (0.1952)	0.87	0.71, 1.07
Newcp	1	0.559	0.082	0.0001 (0.0001)	3.06	2.22, 4.22
Newsba	1	0.141	0.069	0.0419 (0.0419)	1.33	1.01, 1.74
Age	1	-0.035	0.007	0.0001 (0.0001)	0.97	0.95, 0.98
Beach1	1	0.317	0.227	0.1628	n.a.	n.a., n.a.
Beach2	1	0.235	0.206	0.2548	n.a.	n.a., n.a.
Beach3	1	0.083	0.148	0.5767	n.a.	n.a., n.a.
Beach4	1	0.480	0.177	0.0068	n.a.	n.a., n.a.
Beach5	1	-0.493	0.24334	0.1405 (0.0181)	n.a.	n.a., n.a.
Interv1	1	-8.291	49.903	0.8502	n.a.	n.a., n.a.
Interv2	1	1.091	5.084	0.8300	n.a.	n.a., n.a.
Interv3	1	2.195	5.054	0.6641	n.a.	n.a., n.a.
Interv4	1	1.287	5.056	0.7992	n.a.	n.a., n.a.
Interv5	1	0.946	5.073	0.8521	n.a.	n.a., n.a.
Interv6	1	1.554	5.055	0.7586	n.a.	n.a., n.a.
Interv7	1	0.790	5.055	0.8757	n.a.	n.a., n.a.
Interv8	1	1.778	5.054	0.7250	n.a.	n.a., n.a.
Interv9	1	1.951	5.053	0.6995	n.a.	n.a., n.a.
Interv10	1	-8.162	49.069	0.868	n.a.	n.a., n.a.
Interv11	1	1.210	5.095	0.8124	n.a.	n.a., n.a.
Interv12	1	0.995	5.058	0.8441	n.a.	n.a., n.a.
Interv13	1	1.543	5.056	0.7602 (0.0002)	n.a.	n.a., n.a.
Wadeswim1	1	0.011	0.269	0.9663	1.25	0.35, 4.46
Wadeswim2	1	1.199	0.364	0.0010 (0.0022)	1.51	0.33, 6.89

little effect on the risk of respiratory illness. Younger persons had greater odds of contracting respiratory problems than did older persons. Persons who swam before or after the interview day had a slightly increased, and significant risk of respiratory illness over those who did not swim before or after. Contact persons, in contrast to non-contact persons, were at significantly increased risk. Waders were at slightly increased, but not significantly, increased risk of becoming ill. Swimmers were at increased, but not significantly increased risk of becoming ill. If one examines the crude data in Table 5.10, for respiratory illness, waders had an odds ratio of 5.69 (95%c.l. 2.67, 12.10) associated with them, whereas swimmers had an associated value of 2.70 (95%c.l. 1.00, 7.28). Thus, the odds ratios were falsely elevated in the crude data.

The model for eye problems versus the total staphylococci is presented in Table 7.22. The following factors were included in the model: contact person ($p=0.0001$), age ($p=0.0410$), sex ($p=0.1025$), beach ($p=0.1175$), interviewer ($p=0.1384$), the function of the total staphylococcal count ($p=0.5102$), and wadeswim ($p=0.8676$). For the final factor, there was no evidence that it aided in the prediction of eye problems.

Younger persons had greater odds of contracting eye problems than older persons. Sex had little effect on risk of eye problems, although males were at slightly, but not significantly increased risk. The function of the total staphylococcal count had little effect on risk. Contact

Table 7.22 Effect of Selected Variables on Risk of Eye Problems (n=8420 people)

Model: Eye Problems versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-7.023	11.754	0.5502 (0.5502)	n.a.	n.a.
Stwetb	1	0.138	0.209	0.5102 (0.5102)	1.15	0.76, 1.73
Newcp	1	0.648	0.142	0.0001 (0.0001)	3.65	2.09, 6.38
Age	1	-0.024	0.012	0.0410 (0.0410)	0.98	0.95, 0.98
Beach1	1	-1.758	0.886	0.0473	n.a.	n.a., n.a.
Beach2	1	0.626	0.395	0.1126	n.a.	n.a., n.a.
Beach3	1	0.849	0.324	0.0088	n.a.	n.a., n.a.
Beach4	1	0.672	0.399	0.0915	n.a.	n.a., n.a.
Beach5	1	-0.742	0.868	0.3926 (0.1175)	n.a.	n.a., n.a.
Interv1	1	1.639	11.776	0.8893	n.a.	n.a., n.a.
Interv2	1	1.754	11.782	0.8817	n.a.	n.a., n.a.
Interv3	1	2.247	11.742	0.8483	n.a.	n.a., n.a.
Interv4	1	1.381	11.746	0.9064	n.a.	n.a., n.a.
Interv5	1	-9.077	75.741	0.9046	n.a.	n.a., n.a.
Interv6	1	0.285	11.756	0.9807	n.a.	n.a., n.a.
Interv7	1	1.049	11.744	0.9288	n.a.	n.a., n.a.
Interv8	1	2.267	11.741	0.8402	n.a.	n.a., n.a.
Interv9	1	1.483	11.743	0.8995	n.a.	n.a., n.a.
Interv10	1	-9.104	132.97	0.9454	n.a.	n.a., n.a.
Interv11	1	1.677	11.776	0.8867	n.a.	n.a., n.a.
Interv12	1	1.205	11.747	0.9183	n.a.	n.a., n.a.
Interv13	1	1.995	11.743	0.8651 (0.1384)	n.a.	n.a., n.a.
Sex	1	0.063	0.129	0.1025 (0.1025)	1.13	0.16, 14.42
Wadeswim1	1	0.063	0.458	0.8907	1.51	0.16, 14.42
Wadeswim2	1	0.289	0.695	0.6780 (0.8676)	1.90	0.11, 33.43

persons, versus non-contact persons, were at significant risk of developing eye problems. For both waders and swimmers, there was no significant risk of developing eye problems, despite the raised risk for both.

In these last three models, for the function of the total staphylococcal count, the order from the best to worst chi-square p-value was: the skin problem model (p=0.0564), the respiratory illness model (p=0.1952), and the eye problem model (p=0.5102). Once again, the standard errors of these estimates frequently overlapped.

Perusal of Table 5.10 indicates that in the crude data, for eye ailments, the odds ratios for waders (O.R.=3.67, 95%c.l. 1.15, 11.72) and swimmers (O.R.=2.08, 95%c.l. 0.42, 10.36) were both falsely elevated.

7.4.7 Summary of models for swimmers, waders, and persons who did not enter the water.

The four models which appear to best utilize the bacterial counts as predictive indicies of illness, based upon the chi-square p-values, were:

1. overall illness versus P. aeruginosa on mPA (p=0.0496),
2. skin problems versus total staphylococci (p=0.0564),
3. GI illness versus fecal coliforms (p=0.0867), and
4. GI illness versus E. coli (p=0.0885).

Interestingly, the standard errors of the estimates for many of the models overlap, and some of the models yield negative estimates for the function of the bacterial

count. No significance can be attached to the presence of such unexpected negative gradients relating bacterial count to illness.

Of the models investigated, waders were at significantly elevated risk of becoming ill in only 38% of the models tested, whereas swimmers generally (69%) were at slightly elevated risk of illness in the models tested. Interestingly, significance was most frequently attained in the overall illness models. Significantly elevated risks for swimmers were detected in the following models:

1. ear problems versus _P. aeruginosa_ on mTIN (O.R.=7.46, 95%c.l. 1.36, 41.00),
2. ear problems versus _P. aeruginosa_ on mPA (O.R.=6.16, 95%c.l. 1.12, 33.83),
3. overall illness versus _E. coli_ (O.R.=5.65, 95%c.l. 2.33, 13.74),
4. overall illness versus the enterococci (O.R.=4.90, 95%c.l. 2.48, 9.69),
5. overall illness versus the fecal streptococci (O.R.=4.52, 95%c.l. 1.84, 11.09),
6. GI illness versus the fecal streptococci (O.R.=4.28, 95%c.l. 1.14, 16.16),
7. GI illness versus the enterococci (O.R.= 4.08, 95%c.l. 1.32, 12.64), and
8. overall illness versus the total staphylococci (O.R.=3.59, 95%c.l. 1.34, 9.61),
9. overall illness versus _P. aeruginosa_ on mTIN (O.R.=3.58, 95%c.l. 1.99, 6.44).

10. overall illness versus *P. aeruginosa* on mPA (O.R.=3.28, 95%c.l. 1.83, 5.89),

11. overall illness versus fecal coliforms (O.R.=2.37, 95%c.l. 2.02, 13.16),

However, in these models significantly elevated risks were not detected in swimmers:

1. eye illness versus the total staphylococci (O.R.=1.90, 95%c.l. 0.11, 33.43),
2. GI illness versus fecal coliforms (O.R.=1.66, 95%c.l. 0.36, 7.77), and
3. GI illness versus *E. coli* (O.R.=1.65, 95%c.l. 0.37, 7.35).
4. respiratory illness versus the total staphylococci (O.R. 1.51, 95%c.l. 0.33, 6.89),
5. skin problems versus the total staphylococci (O.R.=0.72, 95%c.l. 0.04, 11.55),

In general, these investigations lead one to conclude that there was no evidence to suggest that the function of bacterial count contributed to the prediction of reported illness. If all of the models tested are considered, it appears that swimmers, but not waders, frequently tended to be at significantly elevated risk of becoming ill. Alternatively, if only the overall illness models are considered, both swimmers and waders generally tended to be at significantly elevated risk of becoming ill.

7.5. Logistic regression models for swimmers only

Logistic regression models were also generated for swimmers only, as mentioned previously. These were constructed in order to plot the illness data versus bacteriological count for swimmers. The models for swimmers were constructed and then specific models were selected for plotting using GLIM, as discussed previously.

7.5.1 Overall illness models for swimmers

The model for overall illnes in swimmers versus the total staphylococci is listed in Table 7.23. The following factors were incorporated into this model: contact person ($p=0.0001$), age ($p=0.0001$), interviewer ($p=0.0001$), beach ($p=0.0013$), swimming before or after the interview day ($p=0.0024$), sex ($p=0.0232$), and the natural logarithm of the geometric mean of the total staphylococcal count ($p=0.9657$), which is henceforth referred to as count in sections 7.5.1 to 7.5.6. There was no evidence to suggest that the latter factor contributed to the prediction of reported illness in swimmers. Younger swimmers were at increased risk of becoming ill than were older swimmers. Males were at slightly, but significantly, decreased risk of becoming ill versus females. Persons swimming before or after the interview day were at slightly, but significantly, elevated risk of becoming ill. Contact persons were at significantly increased risk of becoming ill than were non-contact persons. The bacterial count had little effect on the risk of illness for swimmers.

Table 7.23 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.135	0.396	0.0001 (0.0001)	n.a.	n.a.
Stwetb	1	0.003	0.073	0.9657 (0.9657)	1.00	0.87, 1.16
Newcp	1	0.393	0.058	0.0001 (0.0001)	2.19	1.75, 2.75
Newsba	1	0.146	0.048	0.0024 (0.0024)	1.34	1.11, 1.62
Age	1	-0.026	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.115	0.163	0.4828	n.a.	n.a., n.a.
Beach2	1	0.209	0.141	0.1367	n.a.	n.a., n.a.
Beach3	1	0.146	0.102	0.1537	n.a.	n.a., n.a.
Beach4	1	0.481	0.129	0.0002	n.a.	n.a., n.a.
Beach5	1	-0.313	0.215	0.1453 (0.0013)	n.a.	n.a., n.a.
Interv1	1	-0.422	0.564	0.4537	n.a.	n.a., n.a.
Interv2	1	0.665	0.375	0.0760	n.a.	n.a., n.a.
Interv3	1	0.793	0.182	0.0001	n.a.	n.a., n.a.
Interv4	1	0.116	0.199	0.5597	n.a.	n.a., n.a.
Interv5	1	-0.654	0.406	0.1072	n.a.	n.a., n.a.
Interv6	1	0.520	0.171	0.0024	n.a.	n.a., n.a.
Interv7	1	-0.207	0.171	0.2272	n.a.	n.a., n.a.
Interv8	1	0.698	0.173	0.0001	n.a.	n.a., n.a.
Interv9	1	0.514	0.166	0.0020	n.a.	n.a., n.a.
Interv10	1	-1.208	0.945	0.2009	n.a.	n.a., n.a.
Interv11	1	-0.746	0.680	0.2730	n.a.	n.a., n.a.
Interv12	1	-0.374	0.236	0.1126	n.a.	n.a., n.a.
Interv13	1	0.618	0.178	0.0005 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0232 (0.0232)	0.81	0.67, 0.97

In Table 7.24, the model for illness in swimmers versus fecal coliforms is shown. Included in this model were the same factors as found in the previous model: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0007), swimming before or after the interview day (p=0.0022), sex (p=0.0230), and the fecal coliform count (p=0.3825), for which there was no evidence to suggest that it aided in the prediction of reported illness in swimmers.

The same comments hold true for the risks (odds ratios) involved for swimmers (i.e: for specific factors), as for the previous model.

The model for illness in swimmers versus E. coli is shown in Table 7.25, and includes the following factors (see previous two models): contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0006), swimming before or after the interview day (p=0.0022), sex (p=0.0229), and the E. coli count (p=0.219; but the estimate was negative). There was no evidence to suggest that the final factor contributed to the prediction of reported illness in swimmers.

Similar comments with regard to the risks involved for swimmers may be made, as for the previous two models.

The model for illness in swimmers versus the enterococci is outlined in Table 7.26. In this model, the factors incorporated were the same as for the previous models, that is: contact person (p=0.0001), age (p=0.0001), interviewer (p=0.0001), beach (p=0.0003), swimming before

Table 7.24 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus Fecal Coliforms						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-1.804	0.392	0.0001 (0.0001)	n.a.	n.a.
Fecwetb	1	-0.051	0.058	0.3825 (0.3825)	0.95	0.85, 1.06
Newcp	1	0.393	0.058	0.0001 (0.0001)	2.19	1.75, 2.75
Newsba	1	0.147	0.048	0.0022 (0.0022)	1.34	1.11, 1.62
Age	1	-0.026	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.049	0.164	0.7670	n.a.	n.a., n.a.
Beach2	1	0.224	0.115	0.0516	n.a.	n.a., n.a.
Beach3	1	0.111	0.103	0.2812	n.a.	n.a., n.a.
Beach4	1	0.432	0.139	0.0019	n.a.	n.a., n.a.
Beach5	1	-0.083	0.215	0.1892 (0.0007)	n.a.	n.a., n.a.
Interv1	1	-0.468	0.566	0.4084	n.a.	n.a., n.a.
Interv2	1	0.698	0.360	0.0526	n.a.	n.a., n.a.
Interv3	1	0.809	0.183	0.0001	n.a.	n.a., n.a.
Interv4	1	0.104	0.198	0.5981	n.a.	n.a., n.a.
Interv5	1	-0.674	0.407	0.0975	n.a.	n.a., n.a.
Interv6	1	0.538	0.172	0.0018	n.a.	n.a., n.a.
Interv7	1	-0.214	0.170	0.2099	n.a.	n.a., n.a.
Interv8	1	0.717	0.172	0.0001	n.a.	n.a., n.a.
Interv9	1	0.534	0.167	0.0013	n.a.	n.a., n.a.
Interv10	1	-1.228	0.945	0.1937	n.a.	n.a., n.a.
Interv11	1	-0.792	0.682	0.2457	n.a.	n.a., n.a.
Interv12	1	-0.346	0.238	0.1465	n.a.	n.a., n.a.
Interv13	1	0.608	0.178	0.0006 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0230 (0.0230)	0.81	0.67, 0.97

Table 7.25 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus E. coli						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-1.707	0.369	0.0001 (0.0001)	n.a.	n.a.
Ecwetb	1	-0.068	0.055	0.2191 (0.2191)	0.93	0.84, 1.04
Newcp	1	0.393	0.058	0.0001 (0.0001)	2.19	1.75, 2.75
Newsba	1	0.147	0.048	0.0022 (0.0022)	1.34	1.11, 1.62
Age	1	-0.026	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.028	0.162	0.8606	n.a.	n.a., n.a.
Beach2	1	0.232	0.115	0.0443	n.a.	n.a., n.a.
Beach3	1	0.104	0.101	0.3041	n.a.	n.a., n.a.
Beach4	1	0.412	0.139	0.0030	n.a.	n.a., n.a.
Beach5	1	-0.268	0.215	0.2130 (0.0006)	n.a.	n.a., n.a.
Interv1	1	-0.479	0.565	0.3970	n.a.	n.a., n.a.
Interv2	1	0.711	0.360	0.0484	n.a.	n.a., n.a.
Interv3	1	0.816	0.183	0.0001	n.a.	n.a., n.a.
Interv4	1	0.102	0.198	0.6052	n.a.	n.a., n.a.
Interv5	1	-0.681	0.407	0.0941	n.a.	n.a., n.a.
Interv6	1	0.546	0.172	0.0015	n.a.	n.a., n.a.
Interv7	1	-0.215	0.170	0.2060	n.a.	n.a., n.a.
Interv8	1	0.720	0.172	0.0001	n.a.	n.a., n.a.
Interv9	1	0.538	0.166	0.0012	n.a.	n.a., n.a.
Interv10	1	-1.237	0.945	0.1906	n.a.	n.a., n.a.
Interv11	1	-0.803	0.682	0.2388	n.a.	n.a., n.a.
Interv12	1	-0.344	0.237	0.1465	n.a.	n.a., n.a.
Interv13	1	0.606	0.178	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0229 (0.0229)	0.81	0.67, 0.97

Table 7.26 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus Enterococci

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-1.918	0.241	0.0001 (0.0001)	n.a.	n.a.
Entwetb	1	-0.061	0.056	0.2803 (0.2803)	0.94	0.84, 1.05
Newcp	1	0.393	0.058	0.0001 (0.001)	2.19	1.75, 2.75
Newsba	1	0.146	0.048	0.0023 (0.0023)	1.34	1.11, 1.62
Age	1	-0.026	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.044	0.159	0.7792	n.a.	n.a., n.a.
Beach2	1	0.243	0.118	0.0399	n.a.	n.a., n.a.
Beach3	1	0.092	0.107	0.3911	n.a.	n.a., n.a.
Beach4	1	0.454	0.129	0.0004	n.a.	n.a., n.a.
Beach5	1	0.213	0.213	0.1661 (0.0003)	n.a.	n.a., n.a.
Interv1	1	-0.573	0.580	0.3235	n.a.	n.a., n.a.
Interv2	1	0.679	0.358	0.0577	n.a.	n.a., n.a.
Interv3	1	0.818	0.183	0.0001	n.a.	n.a., n.a.
Interv4	1	0.142	0.200	0.4754	n.a.	n.a., n.a.
Interv5	1	-0.642	0.406	0.1139	n.a.	n.a., n.a.
Interv6	1	0.536	0.172	0.0018	n.a.	n.a., n.a.
Interv7	1	-0.179	0.172	0.2976	n.a.	n.a., n.a.
Interv8	1	0.734	0.174	0.0001	n.a.	n.a., n.a.
Interv9	1	0.559	0.169	0.0010	n.a.	n.a., n.a.
Interv10	1	-1.199	0.945	0.2042	n.a.	n.a., n.a.
Interv11	1	-0.896	0.694	0.1964	n.a.	n.a., n.a.
Interv12	1	-0.343	0.237	0.1473	n.a.	n.a., n.a.
Interv13	1	0.644	0.179	0.0003 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0232 (0.0232)	0.81	0.67, 0.97

or after the interview date (p=0.0023), sex (p=0.0232), and the enterococcal count (p=0.2803; but the estimate was negative). The final factor was not important in the prediction of reported illness in swimmers.

The inferences made from the previous models regarding the risk of illness, associated with particular factors, also apply in this case.

In Table 7.27, the model for illness in swimmers versus the fecal streptococci is shown. Once again, the factors included in the model were: age (p=0.0001), contact person (p=0.0001), interviewer (p=0.0001), beach (p=0.0002), swimming before or after the interview day (p=0.0026), sex (p=0.0234), and the fecal streptococcal count (p=0.5471; but the estimate was negative). There was no evidence to suggest that the last factor contributed to the prediction of reported illness in swimmers.

Similar comments regarding the risks of illness, related to particular factors, apply in this case when compared to previous models, and this holds true for the remaining two models as well.

The model for illness versus P. aeruginosa on mPA is outlined in Table 7.28. The following factors were included in the model: age (p=0.0001), contact person (p=0.0001), interviewer (p=0.0001), beach (p=0.0001), swimming before or after the interview day (p=0.0024), sex (p=0.0216), and the P. aeruginosa count (on mPA) (p=0.1237). Once again, there was no evidence to suggest that the latter factor contributed to the prediction of reported illness in

Table 7.27 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus Fecal Streptococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-1.925	0.357	0.0001 (0.0001)	n.a.	n.a.
Strwetb	1	-0.043	0.072	0.5471 (0.5471)	0.96	0.83, 1.10
Newcp	1	0.394	0.058	0.0001 (0.0001)	2.20	1.75, 2.76
Newsba	1	0.145	0.048	0.0026 (0.0026)	1.34	1.11, 1.61
Age	1	-0.026	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.052	0.177	0.7682	n.a.	n.a., n.a.
Beach2	1	0.230	0.118	0.0517	n.a.	n.a., n.a.
Beach3	1	0.118	0.105	0.2603	n.a.	n.a., n.a.
Beach4	1	0.479	0.127	0.0002	n.a.	n.a., n.a.
Beach5	1	-0.316	0.212	0.1360 (0.0002)	n.a.	n.a., n.a.
Interv1	1	-0.463	0.568	0.4146	n.a.	n.a., n.a.
Interv2	1	0.641	0.359	0.0739	n.a.	n.a., n.a.
Interv3	1	0.806	0.183	0.0001	n.a.	n.a., n.a.
Interv4	1	0.124	0.198	0.5311	n.a.	n.a., n.a.
Interv5	1	-0.655	0.406	0.1065	n.a.	n.a., n.a.
Interv6	1	0.537	0.173	0.0020	n.a.	n.a., n.a.
Interv7	1	-0.198	0.171	0.2458	n.a.	n.a., n.a.
Interv8	1	0.7234	0.176	0.0001	n.a.	n.a., n.a.
Interv9	1	0.528	0.166	0.0015	n.a.	n.a., n.a.
Interv10	1	-1.235	0.946	0.1914	n.a.	n.a., n.a.
Interv11	1	-0.786	0.683	0.2502	n.a.	n.a., n.a.
Interv12	1	-0.356	0.238	0.1340	n.a.	n.a., n.a.
Interv13	1	0.626	0.178	0.0004 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0234 (0.0234)	0.81	0.67, 0.97

Table 7.28 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus P. aeruginosa (on mPA)

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.309	0.198	0.0001 (0.0001)	n.a.	n.a.
Pamwetb	1	0.079	0.051	0.1237 (0.1237)	1.08	0.98, 1.20
Newcp	1	0.393	0.058	0.0001 (0.0001)	2.19	1.75, 2.75
Newsba	1	0.146	0.048	0.0024 (0.0024)	1.34	1.11, 1.62
Age	1	-0.027	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.176	0.153	0.2518	n.a.	n.a., n.a.
Beach2	1	0.196	0.115	0.0890	n.a.	n.a., n.a.
Beach3	1	0.253	0.119	0.0334	n.a.	n.a., n.a.
Beach4	1	0.507	0.128	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.430	0.225	0.0562 (0.0001)	n.a.	n.a., n.a.
Interv1	1	0.341	0.566	0.5466	n.a.	n.a., n.a.
Interv2	1	0.767	0.365	0.0354	n.a.	n.a., n.a.
Interv3	1	0.759	0.184	0.0001	n.a.	n.a., n.a.
Interv4	1	0.127	0.198	0.5211	n.a.	n.a., n.a.
Interv5	1	-0.629	0.406	0.1219	n.a.	n.a., n.a.
Interv6	1	0.486	0.173	0.0049	n.a.	n.a., n.a.
Interv7	1	-0.191	0.171	0.2638	n.a.	n.a., n.a.
Interv8	1	0.620	0.179	0.0005	n.a.	n.a., n.a.
Interv9	1	0.477	0.167	0.0043	n.a.	n.a., n.a.
Interv10	1	-1.302	0.946	0.1691	n.a.	n.a., n.a.
Interv11	1	-0.665	0.682	0.3299	n.a.	n.a., n.a.
Interv12	1	-0.370	0.236	0.1165	n.a.	n.a., n.a.
Interv13	1	0.618	0.178	0.0005 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.109	0.047	0.0216 (0.0216)	0.80	0.67, 0.97

swimmers.

The model for illness in swimmers versus P. aeruginosa on mTIN appears in Table 7.29. The factors included in this particular model were identical to those in the six previous models, namely: age (p=0.0001), contact person (p=0.0001), interviewer (p=0.0001), beach (p=0.0003), swimming before or after the interview day (p=0.0025), sex (p=0.0226), and the P. aeruginosa count on mTIN (p=0.3353). There was no evidence to suggest that the last factor influenced the prediction of illness in swimmers.

In summary, the order from lowest to highest p-value for the bacterial count was: P. aeruginosa on mPA (p=0.1237), E. coli (p=0.2191), the enterococci (p=0.2803), P. aeruginosa on mTIN (p=0.3353), fecal coliforms (p=0.3825), fecal streptococci (p=0.9657), and total staphylococci (p=0.9657). There was no evidence to suggest that these bacteria contributed to the prediction of reported illness in swimmers. It is also of interest that the same order applies for the magnitude of the estimates associated with the bacterial counts (i.e: the slope of the lines).

7.5.2 Gastrointestinal illness models for swimmers

The model for GI illness in swimmers versus fecal coliforms appeas in Table 7.30. The factors incorporated into the model were: age (p=0.0001), interviewer (p=0.0001), contact person (p=0.0141), and the fecal

Table 7.29 Effect of Selected Variables on Risk of Illness in Swimmers (n=6653 people)

Model: Overall Illness versus *P. aeruginosa* (on mTIN)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-2.229	0.192	0.0001 (0.0001)	n.a.	n.a.
Patwetb	1	0.057	0.059	0.3353 (0.3353)	1.06	0.94, 1.19
Newcp	1	0.393	0.058	0.0001 (0.0001)	2.19	1.75, 2.75
Newsba	1	0.145	0.048	0.0025 (0.0025)	1.34	1.11, 1.61
Age	1	-0.027	0.004	0.0001 (0.0001)	0.97	0.97, 0.98
Beach1	1	-0.121	0.148	0.4110	n.a.	n.a., n.a.
Beach2	1	0.189	0.117	0.1079	n.a.	n.a., n.a.
Beach3	1	0.178	0.102	0.0798	n.a.	n.a., n.a.
Beach4	1	0.492	0.127	0.0001	n.a.	n.a., n.a.
Beach5	1	-0.373	0.221	0.0919 (0.0003)	n.a.	n.a., n.a.
Interv1	1	-0.396	0.564	0.4830	n.a.	n.a., n.a.
Interv2	1	0.705	0.361	0.0507	n.a.	n.a., n.a.
Interv3	1	0.789	0.182	0.0001	n.a.	n.a., n.a.
Interv4	1	0.111	0.198	0.5763	n.a.	n.a., n.a.
Interv5	1	-0.668	0.406	0.1001	n.a.	n.a., n.a.
Interv6	1	0.520	0.171	0.0024	n.a.	n.a., n.a.
Interv7	1	-0.209	0.171	0.2202	n.a.	n.a., n.a.
Interv8	1	0.665	0.175	0.0001	n.a.	n.a., n.a.
Interv9	1	0.496	0.166	0.0028	n.a.	n.a., n.a.
Interv10	1	-1.200	0.945	0.2038	n.a.	n.a., n.a.
Interv11	1	-0.719	0.681	0.2911	n.a.	n.a., n.a.
Interv12	1	-0.373	0.236	0.1136	n.a.	n.a., n.a.
Interv13	1	0.602	0.179	0.0007 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.108	0.047	0.0226 (0.0226)	0.81	0.67, 0.97

Table 7.30 Effect of Selected Variables on Risk of GI Illness in Swimmers (n=6653 people)

Model: GI Illness versus Fecal Coliforms

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.314	0.619	0.3905 (0.3905)	n.a.	n.a.
Fecwetb	1	0.151	0.088	0.0881 (0.0881)	1.16	0.98, 1.38
Newcp	1	0.268	0.109	0.0141 (0.0141)	1.71	1.11, 2.62
Age	1	-0.032	0.008	0.0001 (0.0001)	0.97	0.95, 0.98
Interv1	1	1.039	6.236	0.8677	n.a.	n.a., n.a.
Interv2	1	3.078	6.176	0.6182	n.a.	n.a., n.a.
Interv3	1	1.799	6.170	0.7706	n.a.	n.a., n.a.
Interv4	1	0.495	6.175	0.9360	n.a.	n.a., n.a.
Interv5	1	0.138	6.235	0.9824	n.a.	n.a., n.a.
Interv6	1	1.508	6.170	0.8070	n.a.	n.a., n.a.
Interv7	1	0.420	6.170	0.9458	n.a.	n.a., n.a.
Interv8	1	1.803	6.169	0.7700	n.a.	n.a., n.a.
Interv9	1	1.823	6.167	0.7676	n.a.	n.a., n.a.
Interv10	1	-7.857	58.341	0.8929	n.a.	n.a., n.a.
Interv11	1	-7.930	55.268	0.8859	n.a.	n.a., n.a.
Interv12	1	0.747	6.177	0.9038	n.a.	n.a., n.a.
Interv13	1	1.742	6.168	0.7776 (0.0001)	n.a.	n.a., n.a.

coliform count (p=0.0881). The final factor mentioned did not attain significance at the 5% level. There was no evidence to suggest that the bacterial count contributed to the prediction of reported GI illness in swimmers, but it was much improved compared to previous models for swimmers.

Examination of the odds ratio data revealed that younger swimmers had greater odds of contracting GI illness versus older swimmers. Contact persons were at significantly elevated risk in contrast to non-contact persons. The bacterial count had little effect on risk.

Table 7.31 shows the model for GI illness in swimmers versus _E. coli_. The factors which were included in the model were the same as for the previous model, namely: age (p=0.0001), interviewer (p=0.0001), contact person (p=0.0141), and the _E. coli_ count (p=0.1021). There was no evidence to suggest that the last factor greatly assisted in the prediction of reported GI illness in swimmers. The comments made about the risks associated with specific factors in the model duplicated those comments made for the first GI model for swimmers.

The model for GI illness versus the enterococci is outlined in Table 7.32. The following factors were included in the model: interviewer (p=0.0001), age (p=0.0001), contact person (p=0.0161), swimming before or after the interview day (p=0.0582), sex (p=0.1227), and the enterococcal count (p=0.7931). There was no evidence to suggest that the final factor contributed to the prediction of reported GI illness in swimmers.

Table 7.31 Effect of Selected Variables on Risk of GI Illness in Swimmers (n=6653 people)

Model: GI Illness versus *E. coli*						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.240	0.6198	0.3971 (0.3971)	n.a.	n.a.
Ecwetb	1	0.141	0.086	0.1021 (0.1021)	1.15	0.97, 1.36
Newcp	1	0.268	0.109	0.0141 (0.0141)	1.71	1.11, 2.62
Age	1	-0.0324	0.008	0.0001 (0.0001)	0.97	0.95, 0.98
Interv1	1	1.012	6.236	0.8711	n.a.	n.a., n.a.
Interv2	1	3.088	6.176	0.6171	n.a.	n.a., n.a.
Interv3	1	1.798	6.170	0.7707	n.a.	n.a., n.a.
Interv4	1	0.501	6.175	0.9354	n.a.	n.a., n.a.
Interv5	1	0.126	6.235	0.9838	n.a.	n.a., n.a.
Interv6	1	1.506	6.170	0.8071	n.a.	n.a., n.a.
Interv7	1	0.428	6.170	0.9447	n.a.	n.a., n.a.
Interv8	1	1.811	6.169	0.7691	n.a.	n.a., n.a.
Interv9	1	1.836	6.168	0.7659	n.a.	n.a., n.a.
Interv10	1	-7.865	58.345	0.8928	n.a.	n.a., n.a.
Interv11	1	-7.956	55.268	0.8855	n.a.	n.a., n.a.
Interv12	1	0.771	6.177	0.9007	n.a.	n.a., n.a.
Interv13	1	1.747	6.169	0.7770 (0.0001)	n.a.	n.a., n.a.

Table 7.32 Effect of Selected Variables on Risk of GI Illness in Swimmers (n=6653 people)

Model: GI Illness versus Enterococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-4.527	6.158	0.4622 (0.4622)	n.a.	n.a.
Entwetb	1	0.022	0.084	0.7931 (0.7931)	1.02	0.87, 1.21
Newcp	1	0.263	0.109	0.0161 (0.0161)	1.69	1.10, 2.59
Newsba	1	0.164	0.087	0.0582 (0.0582)	1.39	0.99, 1.95
Age	1	-0.030	0.008	0.0003 (0.0003)	0.97	0.96, 0.99
Interv1	1	1.006	6.226	0.8716	n.a.	n.a., n.a.
Interv2	1	3.097	6.162	0.6153	n.a.	n.a., n.a.
Interv3	1	1.850	6.155	0.7637	n.a.	n.a., n.a.
Interv4	1	0.501	6.161	0.9352	n.a.	n.a., n.a.
Interv5	1	0.004	6.220	0.9995	n.a.	n.a., n.a.
Interv6	1	1.554	6.155	0.8007	n.a.	n.a., n.a.
Interv7	1	0.451	6.155	0.9416	n.a.	n.a., n.a.
Interv8	1	1.844	6.155	0.7645	n.a.	n.a., n.a.
Interv9	1	1.802	6.153	0.7696	n.a.	n.a., n.a.
Interv10	1	-7.967	58.244	0.8912	n.a.	n.a., n.a.
Interv11	1	-8.086	55.097	0.8833	n.a.	n.a., n.a.
Interv12	1	0.897	6.162	0.8843	n.a.	n.a., n.a.
Interv13	1	1.789	6.154	0.7713 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.133	0.086	0.1227 (0.1227)	0.77	0.55, 1.07

Younger swimmers had greater odds of contracting GI illness versus older swimmers. The enterococcal count had little effect on the risk of GI illness in swimmers. Males were at somewhat, but statistically nonsignificantly, reduced risk of GI illness. Slightly elevated risks were detected for persons who swam before or after the interview day in contrast to persons who did not swim before or after, but were not statistically significant. Contact persons were at significantly elevated risk of GI illness, in contrast to persons who were not contact persons.

The model for GI illness in swimmers versus the fecal streptococci count appears in Table 7.33. The following factors were incorporated into the model: age ($p=0.0001$), interviewer ($p=0.0001$), contact person ($p=0.0145$), and the bacterial count ($p=0.8950$; but the estimate was negative). There was no evidence to suggest that the last factor aided in the prediction of GI illness in swimmers. The odds ratio data behave in the same way as the first two GI models mentioned in this section.

Overall, the order from the best to the worst chi-square p-value for bacterial count in the GI illness models was: fecal coliforms ($p=0.0881$), E. coli ($p=0.1021$), the enterococci ($p=0.7931$), and the fecal streptococci ($p=0.8950$). There was no evidence to suggest that the bacterial counts contributed significantly to the prediction of GI illness in swimmers. As expected, the same order applies for the magnitudes of the estimates associated with the bacterial counts (i.e: the slopes of

Table 7.33 Effect of Selected Variables on Risk of GI Illness in Swimmers (n=6653 people)

Model: GI Illness versus Fecal Streptococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-4.380	6.181	0.4786 (0.4786)	n.a.	n.a.
Strwetb	1	-0.012	0.093	0.8950 (0.8950)	0.99	0.82, 1.19
Newcp	1	0.267	0.109	0.0145 (0.0145)	1.71	1.11, 2.62
Age	1	-0.032	0.008	0.0001 (0.0001)	0.97	0.95, 0.98
Interv1	1	0.841	6.237	0.8927	n.a.	n.a., n.a.
Interv2	1	3.091	6.177	0.6168	n.a.	n.a., n.a.
Interv3	1	1.886	6.171	0.7599	n.a.	n.a., n.a.
Interv4	1	0.527	6.176	0.9319	n.a.	n.a., n.a.
Interv5	1	0.030	6.236	0.9961	n.a.	n.a., n.a.
Interv6	1	1.578	6.171	0.7782	n.a.	n.a., n.a.
Interv7	1	0.482	6.171	0.9377	n.a.	n.a., n.a.
Interv8	1	1.913	6.170	0.7565	n.a.	n.a., n.a.
Interv9	1	1.828	6.169	0.7670	n.a.	n.a., n.a.
Interv10	1	-7.975	58.356	0.8913	n.a.	n.a., n.a.
Interv11	1	-8.128	55.277	0.8831	n.a.	n.a., n.a.
Interv12	1	0.849	6.178	0.8907	n.a.	n.a., n.a.
Interv13	1	1.799	6.170	0.7706 (0.0001)	n.a.	n.a., n.a.

the lines), as for the p-values listed earlier.

7.5.3 Models for ear problems in swimmers

In Table 7.34 the model for ear problems in swimmers versus P. aeruginosa (on mPA) is outlined. The following factors were included in the model: contact person (p=0.0002), age (p=0.0108), beach (p=0.1330), interviewer (p=0.1824), and the bacterial count (p=0.8579; but the estimate was negative). There was no evidence to suggest that the final factor aided in the prediction of reported ear problems in swimmers.

Examination of the odds ratio data reveals that younger persons had greater odds of contracting ear problems than older swimmers. The bacterial count had little effect on risk of ear problems in swimmers, whereas contact persons, versus non-contact persons, were at significantly increased risk.

The model for ear problems in swimmers versus P. aeruginosa (on mTIN) is displayed in Table 7.35. The factors which were considered in this model were: contact person (p=0.0002), age (p=0.0144), beach (p=0.1161), interviewer (p=0.1487), and the P. aeruginosa count (p=0.5359). There was no evidence to suggest that the final factor aided in the prediction of reported ear problems in swimmers. In reference to the risks associated with the factors in this model, the same comments may be made as for the former model.

Table 7.34 Effect of Selected Variables on Risk of Ear Problems in Swimmers (n=6653 people)

Model: Ear Problems versus P. aeruginosa (on mPA)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.526	9.379	0.5557 (0.5557)	n.a.	n.a.
Patwetb	1	-0.024	0.133	0.8579 (0.8579)	0.98	0.75, 1.27
Newcp	1	0.562	0.151	0.0002 (0.0002)	3.08	1.70, 5.56
Age	1	-0.032	0.012	0.0108 (0.0108)	0.97	0.95, 0.99
Beach1	1	-0.308	0.477	0.5178	n.a.	n.a., n.a.
Beach2	1	0.341	0.318	0.2831	n.a.	n.a., n.a.
Beach3	1	0.354	0.316	0.2636	n.a.	n.a., n.a.
Beach4	1	0.633	0.331	0.0555	n.a.	n.a., n.a.
Beach5	1	0.213	0.547	0.6966 (0.1330)	n.a.	n.a., n.a.
Interv1	1	-8.285	81.996	0.9195	n.a.	n.a., n.a.
Interv2	1	2.317	9.399	0.8053	n.a.	n.a., n.a.
Interv3	1	1.737	9.379	0.8531	n.a.	n.a., n.a.
Interv4	1	1.852	9.378	0.8435	n.a.	n.a., n.a.
Interv5	1	0.907	9.416	0.9232	n.a.	n.a., n.a.
Interv6	1	1.895	9.375	0.8398	n.a.	n.a., n.a.
Interv7	1	1.373	9.375	0.8836	n.a.	n.a., n.a.
Interv8	1	2.497	9.375	0.7900	n.a.	n.a., n.a.
Interv9	1	1.980	9.374	0.8327	n.a.	n.a., n.a.
Interv10	1	2.189	9.418	0.8162	n.a.	n.a., n.a.
Interv11	1	-8.272	90.520	0.9272	n.a.	n.a., n.a.
Interv12	1	-0.115	9.416	0.9903	n.a.	n.a., n.a.
Interv13	1	0.013	9.416	0.9989 (0.1824)	n.a.	n.a., n.a.

Table 7.35 Effect of Selected Variables on Risk of Ear Problems in Swimmers (n=6653 people)

Model: Ear Problems versus P. aeruginosa (on mTIN)						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.406	9.378	0.5643 (0.5643)	n.a.	n.a.
Pamwetb	1	-0.097	0.157	0.5359 (0.5359)	0.91	0.67, 1.23
Newcp	1	0.562	0.151	0.0002 (0.0002)	3.08	1.70, 5.56
Age	1	-0.031	0.012	0.0114 (0.0114)	0.97	0.95, 0.99
Beach1	1	-0.307	0.467	0.5110	n.a.	n.a., n.a.
Beach2	1	0.382	0.326	0.2409	n.a.	n.a., n.a.
Beach3	1	0.340	0.276	0.2181	n.a.	n.a., n.a.
Beach4	1	0.631	0.330	0.0562	n.a.	n.a., n.a.
Beach5	1	0.248	0.528	0.6378 (0.1161)	n.a.	n.a., n.a.
Interv1	1	-8.308	81.998	0.9193	n.a.	n.a., n.a.
Interv2	1	2.276	9.398	0.8087	n.a.	n.a., n.a.
Interv3	1	1.742	0.379	0.8527	n.a.	n.a., n.a.
Interv4	1	1.864	9.378	0.8424	n.a.	n.a., n.a.
Interv5	1	0.933	9.416	0.9211	n.a.	n.a., n.a.
Interv6	1	1.886	9.375	0.8406	n.a.	n.a., n.a.
Interv7	1	1.385	9.376	0.8826	n.a.	n.a., n.a.
Interv8	1	2.538	9.374	0.7866	n.a.	n.a., n.a.
Interv9	1	2.000	0.374	0.8311	n.a.	n.a., n.a.
Interv10	1	2.147	9.417	0.8197	n.a.	n.a., n.a.
Interv11	1	-8.295	90.520	0.9270	n.a.	n.a., n.a.
Interv12	1	-0.116	9.416	0.9901	n.a.	n.a., n.a.
Interv13	1	0.041	9.416	0.9966 (0.1487)	n.a.	n.a., n.a.

Neither of these last two models provide clear evidence for a significant role for P. aeruginosa in the prediction of ear ailments (on mTIN, the p-value was 0.5359, and on mPA, the p-value was 0.8579). The estimates (and by implication, the slopes) of the bacterial counts were negative. This suggests that illness rates are lower at higher counts, a feature not found in many of the previous models for swimmers.

7.5.4 Models for skin, respiratory, and eye problems in swimmers

The model for skin problems in swimmers versus the total staphylococci is outlined in Table 7.36. In this model, the following factors were incorporated: interviewer (p=0.0004), contact person (p=0.0140), age (p=0.0190), and the bacterial count (p=0.0947). The last factor, although smaller than for bacterial counts in many other models, provided little evidence that bacterial count contributed to the prediction of reported skin ailments in swimmers.

Examination of the odds ratio data indicates that younger swimmers were at greater odds of acquiring skin problems than older swimmers. Contact persons, in contrast to non-contact persons, were at increased, but not significantly increased risk, and the total staphylococcal count had little effect on risk.

In Table 7.37, the model for respiratory illness versus the total staphylococci is presented. Contact person

Table 7.36 Effect of Selected Variables on Risk of Skin Problems in Swimmers (n=6653 people)

Model: Skin Problems versus Total Staphylococci

Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-7.390	11.918	0.5352 (0.5352)	n.a.	n.a.
Stwetb	1	0.243	0.145	0.0947 (0.0947)	1.28	0.96, 1.69
Newcp	1	0.408	0.166	0.0140 (0.0141)	1.63	0.92, 2.87
Age	1	-0.031	0.013	0.0190 (0.0190)	0.97	0.95, 0.99
Interv1	1	2.790	11.930	0.8151	n.a.	n.a., n.a.
Interv2	1	-6.853	81.524	0.9330	n.a.	n.a., n.a.
Interv3	1	2.460	11.900	0.8362	n.a.	n.a., n.a.
Interv4	1	1.057	11.910	0.9293	n.a.	n.a., n.a.
Interv5	1	1.910	11.929	0.8728	n.a.	n.a., n.a.
Interv6	1	3.374	11.895	0.7767	n.a.	n.a., n.a.
Interv7	1	0.237	11.910	0.9841	n.a.	n.a., n.a.
Interv8	1	3.004	11.896	0.8006	n.a.	n.a., n.a.
Interv9	1	2.317	11.897	0.8456	n.a.	n.a., n.a.
Interv10	1	-7.104	85.980	0.9410	n.a.	n.a., n.a.
Interv11	1	-7.179	91.222	0.9373	n.a.	n.a., n.a.
Interv12	1	2.079	11.902	0.8613	n.a.	n.a., n.a.
Interv13	1	1.160	11.911	0.9224 (0.0004)	n.a.	n.a., n.a.

Table 7.37 Effect of Selected Variables on Risk of Respiratory Illness in Swimmers (n=6653 people)

Model: Respiratory Illness versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-3.431	5.880	0.5595 (0.5595)	n.a.	n.a.
Stwetb	1	-0.113	0.107	0.2877 (0.2877)	0.89	0.72, 1.02
Newcp	1	0.503	0.086	0.0001 (0.0001)	2.73	1.95, 3.83
Newsba	1	0.128	0.071	0.0741 (0.0741)	1.29	0.98, 1.71
Age	1	-0.035	0.007	0.0001 (0.0001)	0.97	0.95, 0.98
Beach1	1	0.271	0.234	0.2473	n.a.	n.a., n.a.
Beach2	1	0.143	0.218	0.5112	n.a.	n.a., n.a.
Beach3	1	0.042	0.154	0.7831	n.a.	n.a., n.a.
Beach4	1	0.515	0.185	0.0054	n.a.	n.a., n.a.
Beach5	1	-0.409	0.336	0.2246 (0.0299)	n.a.	n.a., n.a.
Interv1	1	-8.475	49.694	0.8646	n.a.	n.a., n.a.
Interv2	1	1.270	5.884	0.8291	n.a.	n.a., n.a.
Interv3	1	2.162	5.857	0.7121	n.a.	n.a., n.a.
Interv4	1	1.295	5.859	0.8251	n.a.	n.a., n.a.
Interv5	1	1.046	5.873	0.8587	n.a.	n.a., n.a.
Interv6	1	1.582	5.857	0.7871	n.a.	n.a., n.a.
Interv7	1	0.817	5.857	0.8891	n.a.	n.a., n.a.
Interv8	1	1.794	5.857	0.7594	n.a.	n.a., n.a.
Interv9	1	1.898	5.856	0.7458	n.a.	n.a., n.a.
Interv10	1	-8.367	57.918	0.8851	n.a.	n.a., n.a.
Interv11	1	1.354	5.893	0.8183	n.a.	n.a., n.a.
Interv12	1	1.027	5.861	0.8609	n.a.	n.a., n.a.
Interv13	1	1.621	5.858	0.7820 (0.0017)	n.a.	n.a., n.a.

(p=0.0001), age (p=0.0001), interviewer (p=0.0017), beach (p=0.0299), swimming before or after the interview day (p=0.0741), and the total staphylococcal count (p=0.2877; but the estimate was negative) were incorporated into the model. There was no evidence to suggest that the final factor contributed to the prediction of reported respiratory problems in swimmers.

Swimmers who were contact persons were at significantly increased risk of experiencing respiratory illness, versus non-contact persons. Younger swimmers had greater odds of contracting respiratory problems than did older swimmers. Bacterial count had little effect on risk, similar to to those presented in the previous models. Swimming before or after the interview day was associated with a slight, but not significant, increase in risk, when compared to persons who did not swim before or after.

The model for eye problems in swimmers versus the total staphylococci is shown in Table 7.38, where the following factors were considered in the model: contact person (p=0.0001), sex (p=0.0550), interviewer (p=0.100), beach (p=0.1540), and the total staphylococcal count (p=0.3438). Clearly, there was no evidence to suggest that the last factor contributed to the prediction of reported eye problems in swimmers.

Contact pesons, versus non-contact persons, had a significantly increased risk of eye problems. Male swimmers had a decreased risk of experiencing eye problems, but this was not statistically significant. The total staphylococcal

Table 7.38 Effect of Selected Variables on Risk of Eye Problems in Swimmers (n=6653 people)

Model: Eye Problems versus Total Staphylococci						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-7.614	13.699	0.5783 (0.5783)	n.a.	n.a.
Stwetb	1	0.214	0.226	0.3438 (0.3438)	1.24	0.80, 1.93
Newcp	1	0.499	0.131	0.0001 (0.0001)	2.71	1.62, 4.53
Beach1	1	-1.846	0.897	0.0395	n.a.	n.a., n.a.
Beach2	1	0.429	0.415	0.3017	n.a.	n.a., n.a.
Beach3	1	0.825	0.334	0.0136	n.a.	n.a., n.a.
Beach4	1	0.669	0.426	0.1162	n.a.	n.a., n.a.
Beach5	1	-0.623	0.873	0.4752 (0.1540)	n.a.	n.a., n.a.
Interv1	1	1.807	13.681	0.8949	n.a.	n.a., n.a.
Interv2	1	1.993	13.689	0.8843	n.a.	n.a., n.a.
Interv3	1	2.244	13.652	0.8694	n.a.	n.a., n.a.
Interv4	1	1.419	13.656	0.9173	n.a.	n.a., n.a.
Interv5	1	-9.228	86.938	0.9155	n.a.	n.a., n.a.
Interv6	1	0.360	13.664	0.9790	n.a.	n.a., n.a.
Interv7	1	1.026	13.654	0.9401	n.a.	n.a., n.a.
Interv8	1	2.371	13.652	0.8621	n.a.	n.a., n.a.
Interv9	1	1.078	13.655	0.9371	n.a.	n.a., n.a.
Interv10	1	-9.330	155.257	0.9521	n.a.	n.a., n.a.
Interv11	1	1.937	13.681	0.8874	n.a.	n.a., n.a.
Interv12	1	1.315	13.657	0.9233	n.a.	n.a., n.a.
Interv13	1	2.067	13.653	0.8796 (0.1000)	n.a.	n.a., n.a.
Sex	1	-0.260	0.136	0.0550 (0.0550)	0.59	0.35 1.01

count had little effect on the risk of acquiring eye problems.

In the last three models, for the total staphylococcal count, the order from lowest to highest p-value was: the skin problem model (p=0.09471), the respiratory illness model (p=0.2877), and the eye problem model (p=0.3438).

7.5.5 Summary of models for swimmers

The four best predictive illness models, based on the chi-square p-values, for swimmers were:

1. GI illness versus fecal coliforms (p=0.0881),
2. skin problems versus the total staphylococci (p=0.0947),
3. GI versus E. coli (p=0.1021), and
4. overall illness versus P. aeruginosa on mPA (p=0.1237).

Since all of these p-values were greater than 0.05, there was no evidence that the bacterial counts contributed to the prediction of illness in swimmers. In addition, for these four models, the order from highest to lowest slope was:

1. 0.243 for total staphylococci,
2. 0.151 for fecal coliforms,
3. 0.141 for E. coli, and
4. 0.079 for P. aeruginosa on mPA.

In general, there was no evidence that bacterial count contributed to the prediction of illness in swimmers. Looking at the estimates (slopes), associated with the bacterial counts, as count increased, illness also

increased: skin problems versus the total staphylococci (B=0.243), eye roblems versus the total staphylococci (B=0.214), GI illness versus fecal coliforms (B=0.151), GI illness versus E. coli (B=0.141), illness versus P. aeruginosa on mPA (B=0.079), illness versus P. aeruginosa on mTIN (B=0.057), GI illness versus the enterococci (B=0.022), and illness versus the total staphylococci (B=0.003). In the remaining models, as illness increased, the bacterial counts decreased.

7.5.6 Comments on models for swimmers only

The interviewer effect had to be included in several illness models for swimmers. Removal of the interviewer factor often tended to improve the importance of bacterial count in the models (e.g: for GI illness models versus fecal coliforms, the chi-square p-valiue went from 0.0881 to 0.0396, and for the GI illness model versus E. coli, the value went from p=0.1021 to p=0.0465, and for the skin problem model versus the total staphylococci, the value went from p=0.0947 to p=0.0016. However, removal of the interviewer effect from the models would have biased the results and may have lead to false conclusions.

7.5.7 U.S. and Ontario guidelines: an assessment of their merits

Logistic regression models for swimmers were constructed in order to test the value of existing fecal coliform guidelines in the United States and Ontario. In table 7.39, the results of a test on the American guideline are shown. Bacterial count was divided into two categories, namely, the geometric mean was less than or equal to the U.S. guideline of 200 fecal coliforms per 100 mL of water, or it was greater than the guideline value. In other words, the count was converted from a continuous variable to a discrete variable. The dependent variable in the model was GI illness, based on previous findings and the expected relationships documented earlier in this thesis. The factors included in this model were: interviewer ($p=0.0001$), age ($p=0.0003$), swimming before or after the interview day ($p=0.0519$), and the bacterial count category ($p=0.2857$; but the estimate was negative). The bacterial count category was not important to the model. Thus it appears that a geometric mean guideline of 200 fecal coliforms per 100 mL of water could not be upheld as a suitable guideline in this case, as there was no significant difference in the illness rate amongst swimmers, above and below this dividing point. Examination of the odds ratio data reveals that younger swimmers were at greater risk of acquiring GI illness than older swimmers. Bacterial categorry had little effect on the risk of GI illness in swimmers. Although the lower bacterial category was associated with a somewhat reduced risk of GI illness, the effect was not significant. Whether the

Table 7.39 Effect of Selected Variables on Risk of Gastrointestinal (GI) Illness in Swimmers (n=6653 people)

Model: GI Illness versus U.S. Fecal Coliform Category						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-4.489	6.154	0.4657 (0.4657)	n.a.	n.a.
Usfc	1	-0.123	0.115	0.2857 (0.2857)	0.78	0.50, 1.23
Newcp	1	0.263	0.110	0.0162 (0.0162)	1.69	1.10, 2.60
Newsba	1	0.169	0.087	0.0519 (0.0519)	1.40	1.00, 1.97
Age	1	-0.030	0.008	0.0003 (0.0003)	0.97	0.96, 0.99
Interv1	1	1.091	6.224	0.8608	n.a.	n.a., n.a.
Interv2	1	3.032	6.164	0.6228	n.a.	n.a., n.a.
Interv3	1	1.815	6.157	0.7681	n.a.	n.a., n.a.
Interv4	1	0.507	6.162	0.9345	n.a.	n.a., n.a.
Interv5	1	0.091	6.222	0.9883	n.a.	n.a., n.a.
Interv6	1	1.497	6.157	0.8078	n.a.	n.a., n.a.
Interv7	1	0.447	6.157	0.9421	n.a.	n.a., n.a.
Interv8	1	1.797	6.156	0.7704	n.a.	n.a., n.a.
Interv9	1	1.829	6.154	0.7663	n.a.	n.a., n.a.
Interv10	1	-7.963	58.218	0.8912	n.a.	n.a., n.a.
Interv11	1	-7.979	55.152	0.8850	n.a.	n.a., n.a.
Interv12	1	0.846	6.164	0.8908	n.a.	n.a., n.a.
Interv13	1	1.787	6.155	0.7716 (0.0001)	n.a.	n.a., n.a.

persons swam before or after the interview day posed a slight, but not significant, increase in the risk in contrast to swimmers who did not swim before or after. Contact persons appeared to be at significantly elevated risk of GI illness, in contrast to persons who were not contact persons.

Examining Table 7.40, the Ontario, Canada, guideline of 100 fecal coliforms per 100 mL of water was tested in the same way, such that the fecal coliform count was divided into two groups: those counts less than or equal to 100, and those counts greater than 100. The factors incorporated into the model were: interviewer (p=0.0001), age (p=0.0002), fecal coliform category (p=0.0127), contact person (p=0.0153), and sex (p=0.1146). Interestingly, the fecal coliform category attained significance. This suggests that the Ontario guideline is more appropriate as a dividing point for the data, and that significant differences, in the expected direction, in the numbers of ill swimmers appear above and below this level.

Similar comments may be made regarding the risks associated with age, as for the previous model. Males were at slightly, but not significantly, reduced risk of GI illness versus females. Swimming before or after the interview day was associated with slightly, but not significantly, elevated risks, in contrast to swimmers who did not do this. Contact persons were at significantly increased risk, over non-contact persons, and the bacterial count category had a significant effect on risk (i.e: the

Table 7.40 Effect of Selected Variables on Risk of GI Illness in Swimmers (n=6653 people)

Model: GI Illness versus Ontario Fecal Coliform Category						
Variables	df	Estimate	S.E.	p-value-estimate (p-value-overall)	O.R.	95%c.l.
Intercept	1	-5.144	6.158	0.4035 (0.4035)	n.a.	n.a.
Newfc	1	-0.736	0.295	0.0127 (0.0127)	0.23	0.07, 0.73
Newcp	1	0.266	0.110	0.0153 (0.0153)	1.70	1.11, 2.62
Newsba	1	0.166	0.087	0.0553 (0.0553)	1.39	0.99, 1.96
Age	1	-0.031	0.008	0.0002 (0.0002)	0.97	0.95, 0.98
Interv1	1	0.894	6.220	0.8857	n.a.	n.a., n.a.
Interv2	1	3.056	6.160	0.6199	n.a.	n.a., n.a.
Interv3	1	1.856	6.159	0.7629	n.a.	n.a., n.a.
Interv4	1	0.552	6.159	0.9286	n.a.	n.a., n.a.
Interv5	1	0.124	6.219	0.9841	n.a.	n.a., n.a.
Interv6	1	1.517	6.154	0.8052	n.a.	n.a., n.a.
Interv7	1	0.481	6.154	0.9377	n.a.	n.a., n.a.
Interv8	1	1.912	6.153	0.7560	n.a.	n.a., n.a.
Interv9	1	1.913	6.152	0.7558	n.a.	n.a., n.a.
Interv10	1	-8.021	52.232	0.8904	n.a.	n.a., n.a.
Interv11	1	-8.199	55.086	0.8904	n.a.	n.a., n.a.
Interv12	1	0.867	6.161	0.8817	n.a.	n.a., n.a.
Interv13	1	1.823	6.153	0.7670 (0.0001)	n.a.	n.a., n.a.
Sex	1	-0.136	0.086	0.1146 (0.1146)	0.76	0.54, 1.07

lower category was associated with significantly decreased risk of GI illness).

Findings from these investigations may warrant the continued use of the Ontario guideline, and a re-evaluation of other guidelines. This will be discussed further in Chapter 8.

7.5.8 Graphic representation of multivariate logistic regression models

The methods used to produce graphic displays of the selected logistic regression models have been outlined previously (Section 7.2). The models selected were those with the four best chi-square p-values associated with the bacterial counts (i.e: specifically $\log_{10}$ of the geometric means of the counts).

In Figure 7.1, the logistic regression model results for GI illness versus fecal coliform count is plotted. Using the equation obtained:

$$\log_e(p/1-p)=-4.752$$
$$+0.347 * \log_{10}(\text{geometric mean of the fecal coliform count})$$

at a geometric mean bacterial count of 100, 1.7% (+/-2*0.2) of the swimmers would be expected to become ill with GI problems. The same values at geometric means of 200, 500, and 1000, respectively, would be 1.9%, 2.2%, and 2.5%. The background effect of persons who did not enter the water

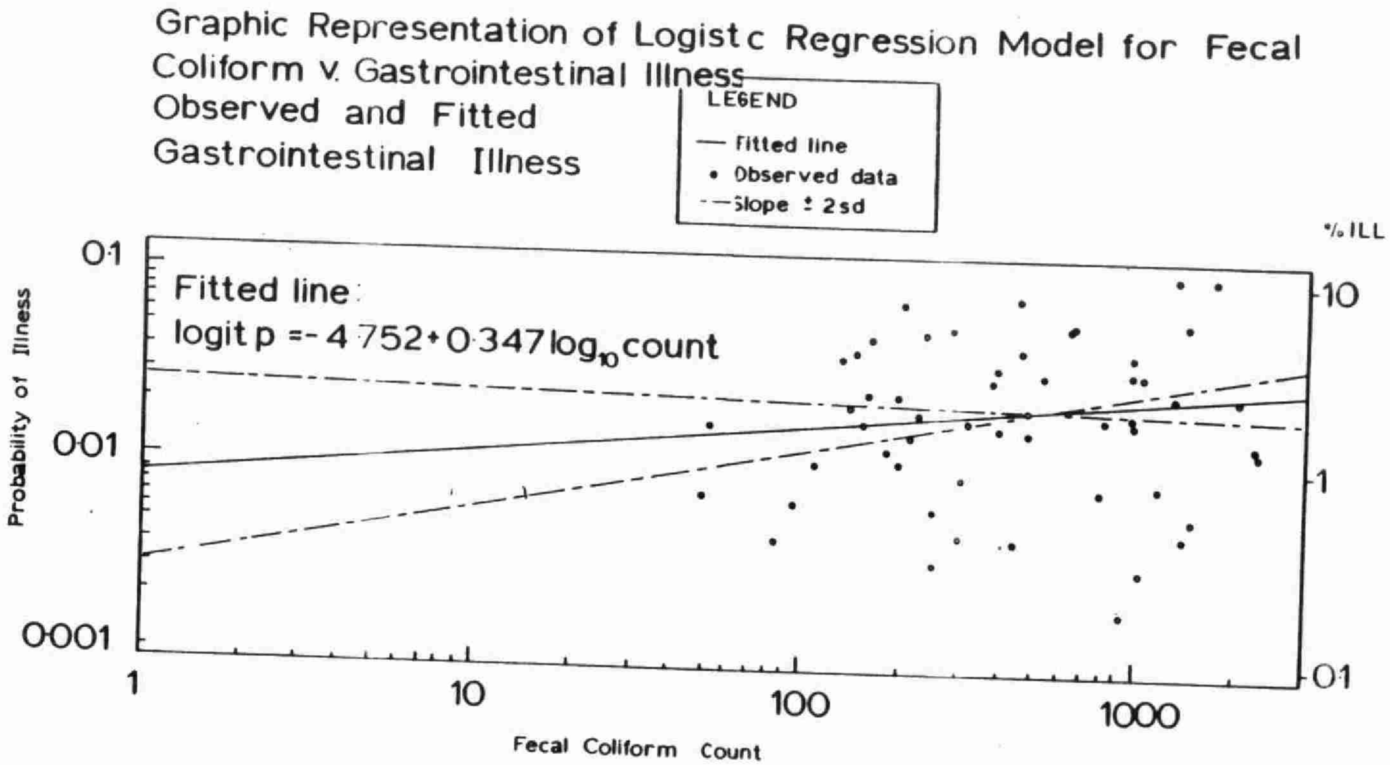

Figure 7.1 Adjusted Log Odds of Swimmers Experiencing Gastrointestinal Illness versus the Fecal Coliform Count

was not included in these models for reasons mentioned previously. However, as a rough comparison, the crude observed rate (p/1-p converted to a percentage) of GI illness in persons who did not enter the water was 0.51%.

The logistic regression model for GI illness versus E. coli is plotted in Figure 7.2. Using the equation obtained:

$$\log_e(p/1-p)=-4.671+$$
$$0.325 * \log_{10}(\text{geometric mean of the } \underline{E}. \ \underline{coli} \text{ count}).$$

At a geometric mean bacterial count of 100, 1.8% (+/-2*0.2) of the swimmers would be expected to become ill with GI problems. The same value at geometric means of 200, 500, and 1000, respectively, would be 2.0%, 2.3%, and 2.5%. As a rough comparison, the crude observed rate of GI illness in persons who did not enter the water was 0.51%

In Figure 7.3, the logistic regression model for skin problems versus total staphylococci is plotted. The eqyuation used was:

$$\log_e(p/1-p)=-6.044+$$
$$0.560 * \log_{(10}\text{geometric mean of the staphylococcal count}).$$

At a geometric mean bacteral count of 100, 0.7% (+/-2*0.3) of the swimmers would be expected to become ill with skin ailments. The same values at geometric means of 200, 500, and 1000, respectively, would be 0.9%, 1.1%, and

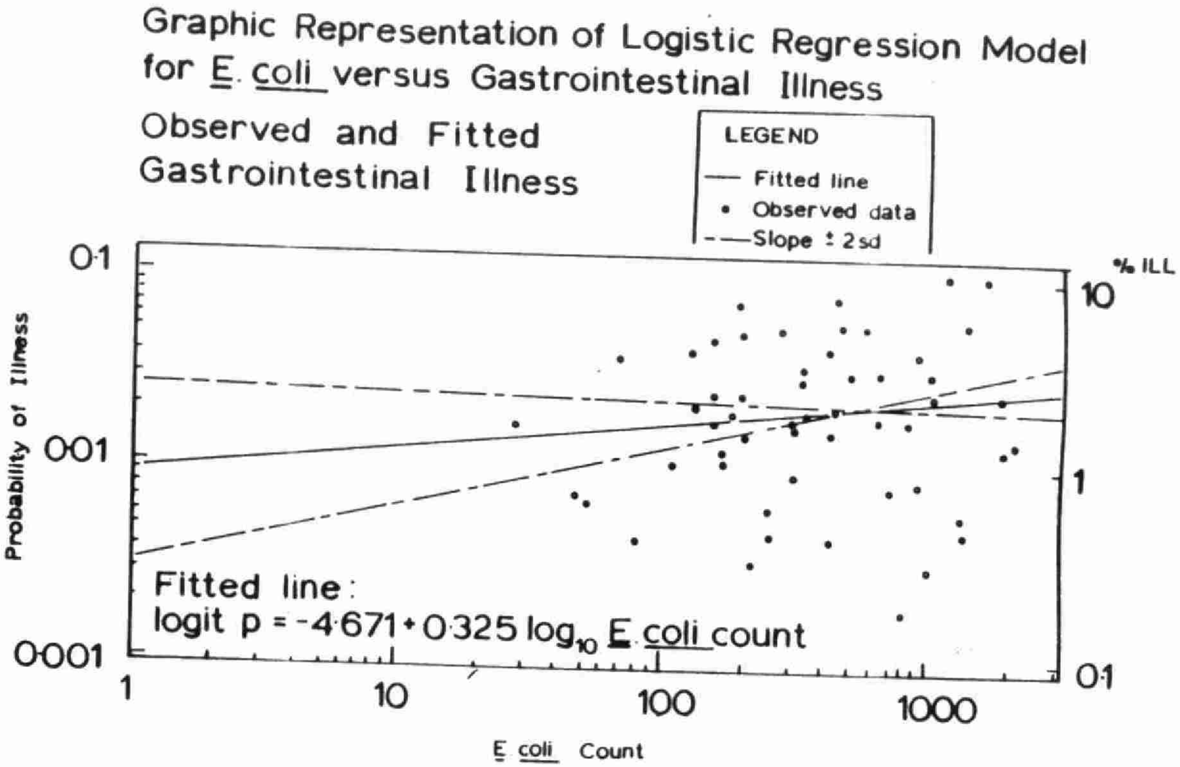

Figure 7.2 Adjusted Log Odds of Swimmers Experiencing Gastrointestinal Illness versus the *E. coli* Count

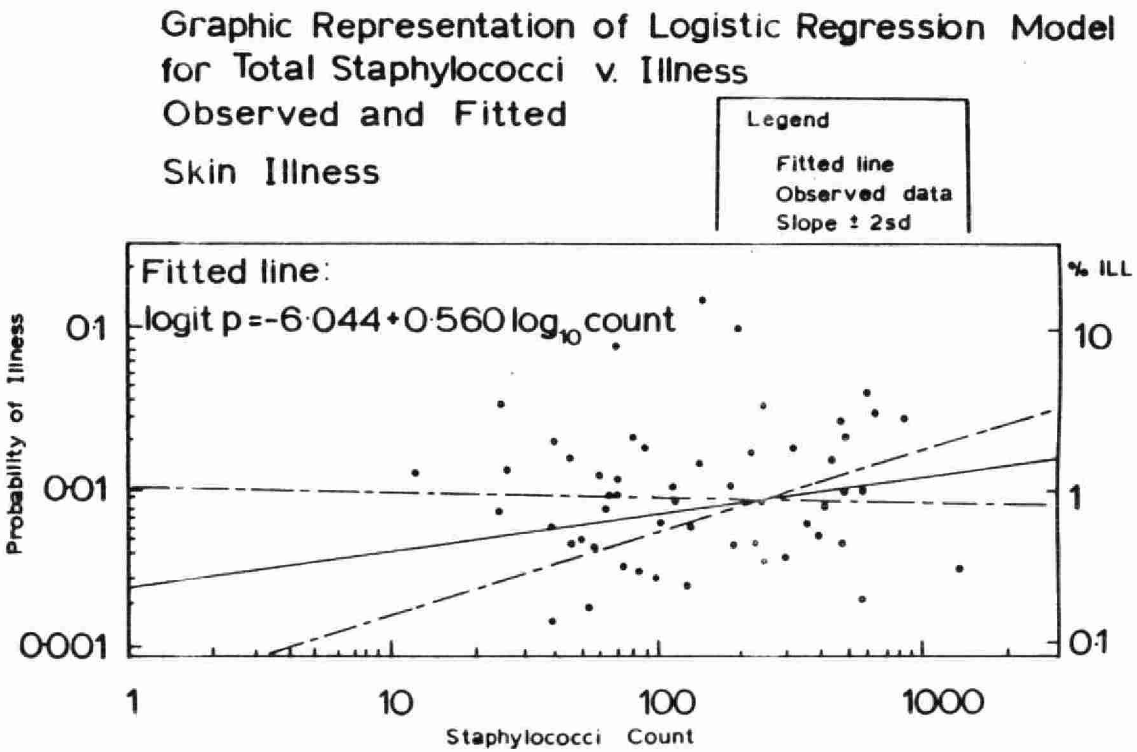

Figure 7.3 Adjusted Log Odds of Swimmers Experiencing Skin problems versus the Total Staphylococcal Count

1.3%. As a rough comparison, the crude observed skin problem rate in persons who did not enter the water was 0.25%.

In Figure 7.4, the logistic regression model for overall illness versus P. aeruginosa is plotted. The equation used is:

$$\log_e(p/1-p)=-2.658+$$
$$0.182 * \log_{10}(\text{geometric mean of the } \underline{P}. \text{ } \underline{aeruginosa} \text{ count}),$$

7% (+/-2*0.1) of the swimmers would be expected to become ill at a geometric means density of 1. The same values at geometric means of 10 and 100, respectively, would be 8.4% and 10%. As a rough comparison, the crude observed rate of illness in persons who did not enter the water was 1.97%.

7.6 Sumarizing remarks

The logistic regression modelling undertaken in this chapter was quite extensive. Admittedly, the assumption made that the probability of becoming ill was linearly and additively related to the risk factors on the logistic scale (Lee, 1986) may be a simplification. Although interactions were not given extensive consideration in the logistic models, the main effect models were considered in great detail, and it was doubtful that significant improvements could be made in this way.

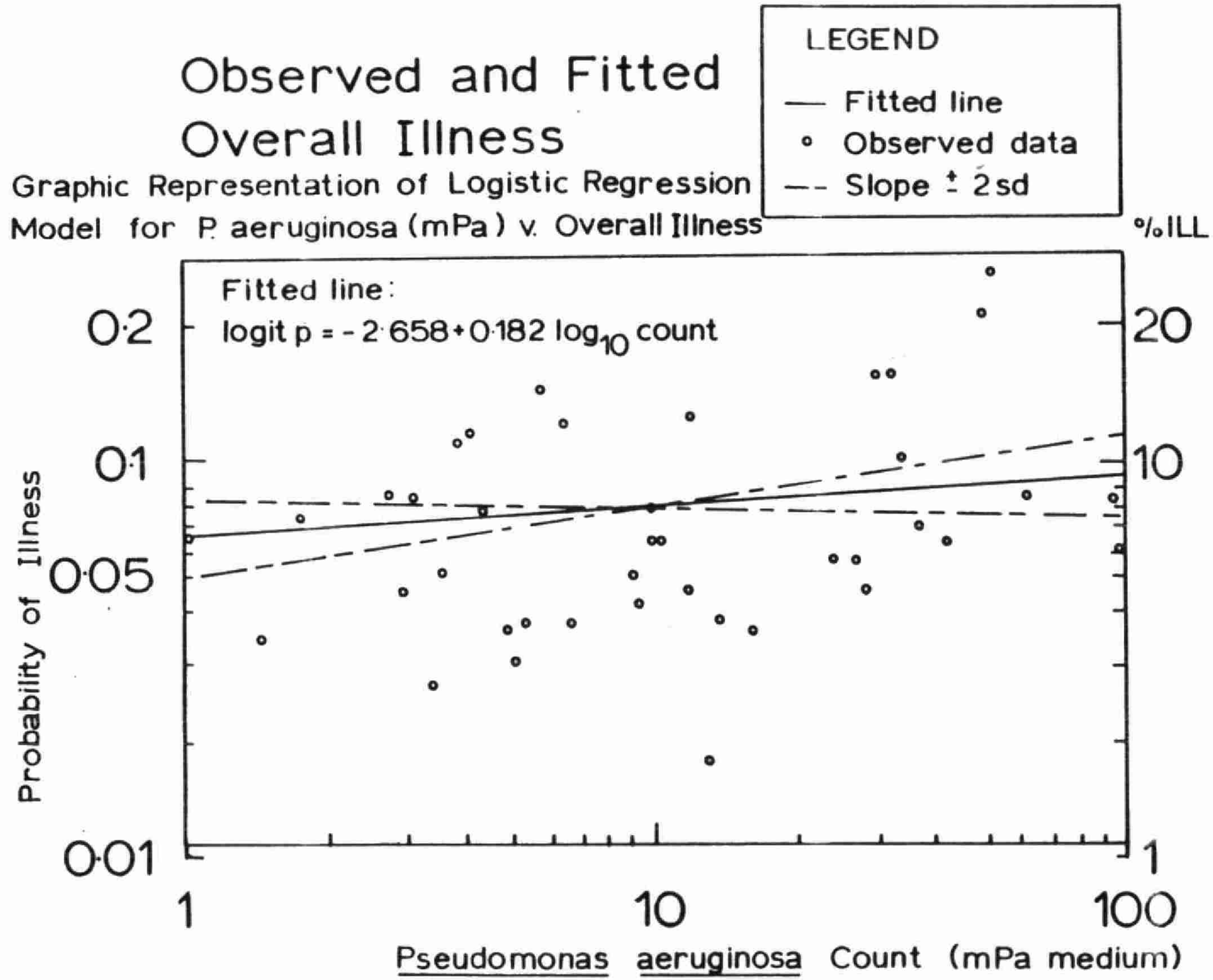

Figure 7.4 Adjusted Log Odds of Swimmers Becoming Ill versus the *P. aeruginosa* (on mPA) Count

It appears that there was no evidence to suggest that the functions of the bacterial counts aided in the prediction of illness and the bacterial counts aided in the prediction of illness in swimmers. However, the data may suggest that in several cases, the swimmers were at significantly elevated risk of contracting illness. The ramifications of these findings are discussed in the next chapter.

CHAPTER 8

DISCUSSION AND SUMMARY

8.1 Preliminary remarks

The aim of this chapter is to consolidate and discuss the microbiological and epidemiological data acquired in this study, and to suggest ways in which the data may be used by the Ontario Ministry of the Environment and other governmental bodies in assessing current microbial water quality guidelines.

8.2 Bacteriological results from the study beaches

The bacteriological data from this study are presented in Chapter 4 of this thesis.

8.2.1 Correlations between bacteria

The best correlation coefficient to emerge between the bacteria enumerated (i.e: the $\log_{10}$counts for: heterotrophs, *E. coli*, fecal coliforms, the enterococci, the fecal streptococci, the total staphylococci, *P. aeruginosa* (on mPA medium), and *P. aeruginosa* (on mTIN medium)), in this study, was that for *E. coli* versus fecal coliforms (r=0.985). This tight correlation suggests that 86% of the fecal coliforms were *E. coli* (based on the overall data). Interestingly, in Ontario 91.4% of more than

7700 fecal coliform isolates recovered from various water samples were confirmed to be *E. coli* (Vlassoff, 1981; Ministry of National Health and Welfare, 1983) by the Ontario Ministry of the Environment. In addition, Dufour (1977) examined 28 human fecal samples by membrane filtration and showed that 96.8% of the fecal coliforms detected were *E. coli*, 1.5% were *Klebsiella* sp., and 1.7% were in the *Enterobacter* - *Citrobacter* group.

The second best correlation, which emerged in the data from this study, was that between *P. aeruginosa* (on mPA medium), and *P. aeruginosa* (on mTIN medium) (r=0.785). While this value is not as good as the fecal coliform versus *E. coli* relationship (presumably largely due to the two to three orders of magnitude difference in the densities of the organisms detected in the study), these data provide support for the accuracy of the *P. aeruginosa* results, as well as indicating that both of the media used for *P. aeruginosa* enumeration may well be appropriate for use in test laboratories. However, further work is required to ascertain whether the consistency of the two techniques in enumerating *P. aeruginosa* is related to the fact that only fresh recreational waters were sampled.

Moderate to good relationships (i.e: values of the correlation coefficient between 0.50 and 0.75 - Colton, 1974), were found between: fecal coliforms and the fecal streptococci (r=0.574), *E. coli* and the fecal streptococci (r=0.551), fecal coliforms and the enterococci (r=0.519), the total staphylococci and the fecal streptococci

(r=0.519; the only relationship for which both members tested were not of fecal origin), the enterococci and the fecal streptococci (r=0.501), and _E. coli_ and the enterococci (r=0.501). Reference to Table 1.4 (Chpater 1) reveals the various sources of most of these organisms. It should also be noted that fecal streptococci occur in the feces of both humans and warm-blooded animals, and are often recovered from fecally-contaminated water, but apparently do not multiply in naturally or fecally-contaminated waters or soils (Clausen _et al._, 1979).

These data suggest that it may be worth investigating whether governmental test laboratories can concentrate their efforts on determining fewer bacterial types in fresh recreational water samples. Clearly there is also a need to consider the merits of the methodologies involved and their appropriate costs.

8.2.2 Correlations between bacterial counts, air temperature, and water temperature

None of the correlation coefficients calculated between bacteria and air or water temperature exceeded 0.28. This suggests that air and water temperature were not the only controls on the densities of the various bacteria. As a result, inclusion of these variables in subsequent multivariate analysis was considered to be of secondary importance.

8.2.3 Bacterial geometric means

The overall (i.e: for open and closed beaches, collectively) fecal coliform geometric mean data (i.e: 432), and fecal coliform data for open (423) and closed (453) beaches, in this study, exceeded both Canadian (Ministry of National Health and Welfare, 1983) and Ontario (Ontario Ministry of the Environment, 1978) guideline values of 200 organisms per 100 mL of water, and 100 organisms per 100 mL of water, respectively. Consequently, the possibility of potentially recognizable health risks at the open beaches was of particular interest.

It was apparent that the closure of the beaches investigated had no significant effect on the fecal coliform counts. However, important questions were raised about the criteria adopted for beach closure, and whether closure actually has the desired effect of reducing the count. It may be recalled that beach closure did not occur simultaneously, was based on the opinions of various agencies, and spanned varying periods of time. Apart from the total staphylococci and the enterococci, the closure of the beaches investigated had no significant effect on the bacterial counts. In fact, the counts were often higher over the periods when the beaches were closed compared to when they were open. The statistically significant increase in the total staphylococcal counts detected at the open versus the closed beaches might, to some extent, reflect the shedding of staphylococci by bathers.

Interestingly, the *E. coli* geometric means for the overall data (370), and the open (361) and the closed (390) beaches were well above 100 organisms per 100 mL of water, as well as 126 *E. coli* per 100 mL (the proposed value recently put forward by the United States Environmental Protection Agency for criticism as a future guideline for fresh recreational waters - U.S. Environmental Protection Agency, 1986). The recently proposed fresh water guideline, is based on the work of Cabelli (Cabelli *et al*., 1982; Cabelli, 1980) and Dufour (1982, 1984, 1985 in draft). The work of Cabelli and Dufour appears to suggest that the guideline is based on the acceptance of eight gastrointestinal illnesses per 1000 fresh water swimmers.

The geometric means for the total staphylococci exceeded the previously recommended, but inadequately tested, guideline value of 100 organisms per 100 mL of water (Brown, 1983). Values were 125 overall, 142 for open beaches, and 96 for closed beaches. Once again, the potential for health effects at the open beaches warranted serious investigation.

The detection of the potential pathogen, *P. aeruginosa*, at open beaches was of particular concern, since it can produce ear infections in persons who enter recreational waters (Hoadley, 1977; Seyfried, 1973), as well as other types of infections (Ministry of National Health and Welfare, 1983; Hoadley, 1977).

Although ordering of the geometric mean data was completed by month, beach, and beach and status, frequent

overlapping values of the standard errors of the arithmetic means suggests that these orders must be treated with extreme caution. Furthermore, given the erratic nature of the beach closures in the summer of 1983, it was impossible to maintain consistency in the sampling procedures.

The bacterial geometric mean data for each month were determined, and the Canadian and American fecal coliform guidelines were exceeded during June (310), July (555), and August (550), in this study. In addition, the E. coli values were well above both 100 organisms per 100 mL of water and 126 organisms per 100 mL of water during June (272), July (479), and August (278). The potentially opportunistic pathogen, P. aeruginosa was detected during all three months of the study. Finally, the geometric means for the total staphylococci exceeded 100 per 100 mL of water in June (291), and July (169), but not in August (74). The possible health ramifications of these data merited examination.

Examination of the bacterial geometric mean data by beach (despite the differences in the numbers of samples collected at each beach) suggested that there was less bacterial contamination at Professor's Lake and Albion Hills Conservation Area, compared to Kelso, Boyd, and Claireville Conservation Areas. Considerable variation was detected at Heart Lake Conservation Areas (C.A.'s). In addition, both the Canadian and Ontario geometric mean fecal coliform guidelines were exceeded at all of the study beaches. The same was true for the E. coli guideline values

of 100 and 126 organisms per 100 mL of water. P. aeruginosa was isolated at each of the study beaches and this suggested the potential possibility of widespread infection problems. The total staphylococcal geometric means exceeded 100 per 100 mL of water at all of the study beaches apart from Professor's Lake and Albion Hills C.A. Thus, concern about the health of water recreationalists was generated throughout the entire study area.

Comments concerning the beach and status (i.e: open versus closed) data have already been made (Section 4.1.10). Recall that only Albion Hills C.A. and Professor's Lake were never closed during the study period. However, both the Canadian and Ontario fecal coliform guidelines were surpassed at all open and closed beaches. The same held true for the E. coli values of 100 organisms and 126 organisms per 100 mL of water, respectively. P. aeruginosa was detected at all open and closed beaches. The total staphylococcal geometric means exceeeded 100 per 100 mL of water at all of the open beaches except for Albion Hills C.A. and Professor's Lake, and at all the closed beaches except for Boyd C.A.

Clearly, the excessive numbers of bacteria detected at the study beaches, in the summer of 1983, provided several reasons to express concern regarding possible potential public health effects, given the present guideline values, and assuming their relevance as adequate measures reflecting health effects. Should no evidence be found for excessive health effects at these elevated bacterial

concentrations, then serious evaluation of these guidelines may be considered necessary.

8.3 Results from Professor' Lake pilot bacteriological study

Samples collected from the nearshore environment at Professor's Lake revealed that the geometric mean values were higher than values obtained from water samples collected offshore on each of three sampling dates. However, comparison of the arithmetic means revealed that these differences were not statistically significant at the 5% level when the standard deviations were compared, although the nearshore values were consistently higher than the offshore values on each of the three days.

The bacterial counts obtained for duplicate samples from defined sites at Professor's Lake showed an equivalent amount of scatter about the arithmetic mean when compared to the overall nearshore beach data on the third day of sampling.

These data suggest that firstly, although samples from the nearshore environment tended to produce consistently higher bacterial counts than offshore samples, these results appeared not to be statistically significant. This suggests that the location at which samples were collected is not of critical importance in this case. Secondly, the duplicate samples from the nearshore environment provided evidence that a single sample of water provides an adequate

representation of the bacterial content of the water. Whether these four results apply for other locations is not well constrained at present, and requires further study. For the present, it was judged prudent to collect at least two nearshore samples at each open beach, from areas with a high bather load.

8.4 Results from the Humber River bacterial and trace element study

Higher bacterial concentrations were detected in the East Humber River near Woodbridge and King City (where the levels of human habitation are high) in contrast to the lower levels detected in the agricultural areas between these two built-up areas. These results were reproduced on two separate days.

Findings from the less densely inhabited West Humber River indicated that there was an overall trend of decreasing bacterial contamination as one travelled up-river on the first sampling day. This trend was not evident on the second day.

High levels of Ca, Mg, and S were detected in relation to other elements in all of the river samples. However, there were no coherent variations in the trace element concentrations on either of the days on which samples were collected. Furthermore, there were no tight relationships between the bacterial counts and trace element concentrations.

Provincial water quality objectives for trace elements were not exceeded (Ontario Ministry of the Environment, 1978).

8.5 Assessment of bacterial methodology

Strict adherence to standard and consistent methods of collection and bacterial analysis of the surface water samples collected was maintained throughout the entire study. As mentioned, previously, the water samples were collected at a water depth of approximately 50 cm, in a location of a high density of swimmers (Seyfried *et al.*, 1985b). Cabelli (1980) and his colleagues (1982; 1979) obtained water samples at chest depth. The former procedure was preferable since it would more likely provide a representative estimate of the health risks for the majority of the persons exposed in the specific area. In addition, Cabelli and his colleagues usually collected three to four samples daily at two or three sites from each beach (Cabelli *et al.*, 1982), whereas open beaches were sampled twice daily in this investigation. Multiple site sampling and more frequent sampling might more accurately constrain the water quality, but the limited data from Professor's Lake suggests that the improvement may be of limited importance.

It is also important to note that the mTEC medium was used for fecal coliform and *E. coli* enumeration in this study, whereas Cabelli (1980) and his colleagues (1982;

1979) used mC medium for fecal coliforms and for _E. coli_ before 1974 (mTec was used after 1974). Both studies employed mE medium for enumeration of the enterococci. In addition, Cabelli and his associates (1982; 1979) employed the MPN (Most Probable Number) procedure to obtain total and fecal coliform densities. Densities of total coliforms (i.e: _Escherichia_ sp., _Klebsiella_ sp., and _Citrobacter - Enterobacter_ sp.) were also measured using the MF (Membrane Filtraion on MC medium) procedure. The MF procedure was used for _P. aeruginosa_, _Clostridium perfringens_, _Aeromonas hydrophilia_, _Vibrio parahaemolyticus_, and the enterococci. Thus, the methodologies used in the studies differed from those presented here, and these differences should be considered when comparing or contrasting the results of these studies.

The MF (Membrane Filtration) procedure was utilized for isolation of: the total staphylococci, fecal coliforms and _E. coli_, fecal streptococci, the enterococci, and _P. aeruginosa_. A plate count was done for heterotrophic bacteria. A list of the relative advantages and disadvantages of the techniques is presented by McNeill (1985). According to the Canadian government, the MF method has a higher degree of reproducibility, is rapid, easy to perform, does not require as much space, labour, or equipment, as the MPN procedure, and can be used to test large volumes of water directly in the field, if required (Ministry of National Health and Welfare, 1983). However, the Canadian government warned that many people have

detected highly significant differences between various membrane brands in their ability to recover total and fecal coliforms from natural waters and pure cultures. In fact, Tobin and Dutka (1977; Ministry of National Health and Welfare, 1983) noted that newer types of filters with the largest surface pore size and fastest flow yielded the highest bacterial recovery, and recommended the use of one brand and lot number in a laboratory, throughout a season.

Interestingly, Stevenson (1953), an early investigator of swimming-related illness, employed MPN procedures for total coliform determinations, and another of his contempories, Moore (1959), used even more elementary procedures.

Laboratory quality control assessments conducted by blind sample assessment periodically throughout the study, yielded bacterial results of high quality. Additional confidence in the data resulted because the microbiological teams were trained and supervised by water quality experts at the Ontario Ministry of the Environment.

Neither of the pathogens <u>Campylobacter jejuni</u> nor <u>Legionella pneumophila</u> were detected in this investigation.

A major concern in the area of bacterial recreational water quality assessment is the lack of consistent and precisely defined sampling and isolation procedures (Section 1.6), as well as the ambiguity and misaplication in the literature of the statistical procedures adopted (McNeill, 185), such as the type of mean employed in the evaluation of the bacterial water quality. According to

Tillet and Coleman (1985), bathing and drinking water sources are likely to contain bacteria in varying densities (other than purely random variation), and the only way to study bacterial distribution in such waters is to collect a series of samples appropriately planned in place and time. Brenniman et al. (1981) found, in a small study performed over three weekends at two Lake Erie beaches, that bacterial concentrations varied significantly ($p<0.05$). with the time of day, and day of weekend collection, but did not vary significantly at various locations in the swimming area (refer to section 1.2 for a detailed description of their sampling procedures).

To date, there has been no general consensus as to the importance of the following in describing bacterial water quality, nor have these points been adequately addressed and discussed in many bacterial water quality guideline specifications (see Tables 1.6 and 1.7).

1. Whether or not a series (with precise determination of the number) of water samples should be collected at any one sample time.

2. Whether or not water sample(s) should be collected at specific time(s)of day.

3. Whether or not the collection of a water sample(s) should be undertaken at several times per sample day.

4. The importance of the day of the week in sample collection, and in relation to the above points.

5. The role of bather density in all of the above points.

In fact, only quite recently have the Canadian,

American, and Ontario governments addressed these problems (U.S. Environmental Protection Agency, 1986; Ministry of National Health and Welfare, 1983), and then only in a preliminary manner. The Canadian government has advocated more frequent sample collections at locations and times of heaviest beach use (Ministry of National Health and Welfare, 1983). Weekends, holidays, and times when maximum pollution can be expected (e.g: during storm water runoff, sewage by-passing, high onshore winds etc.) were also considered necessary for inclusion in sampling regimes. Samples from estuarine and marine bathing areas should be collected at high, slack, and low tides to ascertain cyclical water quality, according to the Canadian government. Whenever any sample exceeds 400 fecal coliforms per 100 mL, immediate resampling of the area is necessary. In addition, it was stated that samples of bathing beach water should be obtained from representative areas at each location where there is greatest bather density, and upstream of peripheral areas (where appropriate) where natural and man-made drains could discharge stormwater, septic tank effluent, or runoff from garbage collection areas. For the Canadian government, composite samples are not an acceptable alternative. Individual samples must be collected and analyzed.

The U.S. Environmental Protection Agency (1978) advocated daily sampling of recreational waters, preferably in afternoons, as the optimum frequency in the bathing season. Even more recently, further recommendations have

been proposed for consideration (Section 8.11.1 - U.S. Environmental Protection Agency, 1986).

In the Province of Ontario, a series of at least ten samples per month per sample location is advocated for recreational waters, but an increased sampling frequency is considered necessary when the water is used for recreational purposes or subjected to contamination or discharge (Ontario Ministry of the Environment, 1978).

At present, sampling regimes, in general, are rather poorly defined, vague and inconsistent, both between and within countries. There may be an advantage in establishing, as far as possible, more universal sampling criteria, and presenting bacterial geomteric mean data calculated on similar sampling frequencies. Clearly, there appears to be some debate as to the importance of hourly variability in bacterial concentrations, and the role of meteorological effects on such variation.

8.6 Virological data

In the investigation, no viruses were isolated on any of the Sunday sample dates. The lack of detection of viruses does not imply their absence, because the present detection methodology method may have associated sources of error. For example, there is a need for chemical alteration of the sample, inactivation of certain enteric viruses at strongly acidic and basic pH's, and the formation of floss. Furthermore, there are temporal variations in sample

quality, complexity and unreliability (Sobsey and Jones, 1979; Sobsey _et al_., 1980; McNeill, 1985), poor virus recovery due to adsorption and inefficient elution from dialysis membranes (Cliver, 1967; McNeill, 1985), concentration of non-dialysiable cytotoxic sewage components (Shuval _et al_., 1967; McNeill, 1985), and a sample size restriction (APHA, 1980; McNeill, 1985).

In the laboratory, severe toxicity problems were encountered on most first passages in tissue culture. Most tissue culture cells were killed within three days of inoculation resulting in great impairment in virus recovery. In addition, problems were encountered with the sterilization of the final concentrate through the 0.22 um filter, and consequently, many first tissue culture passages were contaminated. Elimination of this contamination was attempted, but the extent of impaired virus recovery was unknown.

The lack of detection of viruses in this study, most likely, was due to the limitations of procedures employed, rather than the absence of viruses. Under ideal conditions, it has been estimated that the virus recovery procedures are no more than 15% efficient at recovery of enteric viruses from environmental waters (G. Jenkins, personal communication). In addition, the severe toxicity and contamination problems experienced in this investigation would have reduced the recovery efficiency even more.

McNeill (1985) has listed several pathogenic viruses and their associated clinical syndromes which may

potentially be waterborne (Table 1.1) including: polioviruses, Coxsackieviruses A and B, echoviruses, hepatitis A, non-A, and non-B viruses, Norwalk and other parvovirus-like agents, rotaviruses, and influenza A viruses. She also mentioned that adenoviruses and adenosatelloviruses may potentially be transmitted by water contact.

McNeill (1985) also provided human minimum infective dose figures for some viral pathogens (see Table 1.3). In an earlier paper, Shuval (1975) revealed that there was ample evidence that ingestion of a single pathogenic virus (or bacterium) can, in some instances, result in infection and disease, and also that bathers tend to ingest 10 to 50 mL of water in a single day of exposure. Shuval concluded that there was a risk of becoming infected from bathing in sewage-contaminated water which would increase as the level of sewage contamination increases, and in areas of high enteric disease rates.

According to the Canadian government, the viruses which are most important in waterborne disease are the enteric viruses (Ministry of National Health and Welfare, 1983), including the following: enteroviruses (polioviruses, echoviruses, and Coxsachieviruses), reoviruses, adenoviruses, rotavirus, hepatitis A and other enteric viruses, including gastroenteritis-associated viruses and the Norwalk agent (Environmental Health Directorate, 1977; Ministry of National Health and Welfare, 1983). Although these viruses may originate in animal

wastes, the majority of the pollution may be attributed to municipal sewage or other human waste sources (Ministry of National Health and Welfare, 1983). In addition, the type of enteric viruses detected depends on the sensitivity of the methodology used, and for some viruses, no quantitative methods exist for enumeration (e.g: hepatitis A and the parvovirus-like agents), whereas for others such as the rotaviruses, such detection methods exist, but require refinement (McNeill, 1985). Noteably, viruses from human sources are excreted only by infected persons, unlike fecal coliform bacteria which may be detected in almost all individuals (U.S. Environmental Protection Agency, 1978; Ministry of National Health and Welfare, 1983). Viruses may be isolated in the absence of fecal coliforms (Berg, 1978; Ministry of National Health and Welfare, 1983), and significant levels of virus have been detected when recreational waters met the bacterial guidelines (Goya et al., 1978; Ministry of National Health and Welfare, 1983). In fact, there appears to be no constant ratio of fecal coliforms to enteric viruses (Berg and Metcalf, 1978; Ministry of National Health and Welfare, 1983).

Cabelli (1983) emphasized that little evidence exists to suggest that water-related transmission routes have been significant in the transmission of viral diseases, except for infectious hepatitis caused by hepatitis A and acute gastroentiritis caused by the Norwalk-like viruses and the human rotaviruses. However, Cabelli believs that infectious hepatitis and acute gastroenteritis appear to be the most

serious and prevalent, respectively, of the water-related diseases.

In this investigation, the predominant types of illnesses (respiratory and gastrointestinal ailments) detected in swimmers (and waders) may well be of viral origin given the potential susceptibilities and ages of the people examined, the necessary approximate incubation periods of detected disease, the lack of disease severity, and the study areas (from which no indications of outbreaks of bacterial origin arose) examined. Confirmation of these suspicions would only have been possible by obtaining medical assessment of clinical cases and acquiring associated laboratory specimens. This however was prohibitively expensive in this particular study.

Some scietists have advocated the establishment of viral standards for recreational waters (Ministry of National Health and Welfare, 1983). For example, Shuval (1975; Ministry of National Health and Welfare, 1983) advocated the absence of enteric viruses in 100 L, of seawater. Melnick (1976) recommended a limit of one detectable infectious viral unit per 10 U.S. gallons (37.9 L) of recreational water (Ministry of National Health and Welfare, 1983). Payment (1977), a Canadian virologist, advocated a standard of one tissue culture infectious dose in 40 L and Sattar (1978) suggested that one detectable infective unit of human pathogenic virus in 10 L be permitted when a 100 L sample is examined (Ministry of National Health and Welfare, 1983).

More recently, Payment (1984) calculated that the risks involved in bathing in virus contaminated waters would be less than 25 cases per 1000 bathers (about 25 to 50 cases per 1000 persons was considered to be the epidemic level) using a standard of under 25 viruses per litre, and less than one case per 1000 bathers using a standard of the absence of viruses in 1 L of water. Payment concluded that it should be possible to reduce the risk of contamination to an undetectable level by the absence of viruses in 1 to 10 L of water, in water containing fewer than 10 enterococci per 100 mL (based upon the work of Cabelli et al., 1982), and when the present bacterial standards are met.

Although viral standards have been proposed, several problems exist at present, which might detract from their widespread use. The time period required for their isolation and identification, which often takes several days or weeks, is too lengthy, and current quantitative methods, if they do exist, are not very precise (Cabelli et al., 1975). In addition, the methods are often not standardized, are time-consuming, and require special facilities (McNeill, 1985). McNeill also warned that the use of the enteric viruses as indicators of other viruses which might be present in the water has limitations, and might lead to similar problems to those encountered with current bacterial systems.

Thus, problems do exist, at present, which prohibit widespread adoption of viral standards. However, improved

methodology is definetely required in this area, and if well developed, will necessitate careful examination of specific viruses (e.g. enteric viruses) as potential recreational water quality indicators.

8.7 Evaluation of epidemiological study design

Recent investigations of swimming-related illness, which used regression modelling to predict such illness, were undertaken by Cabelli and his associates (Dufour, 1985, in press, Dufour, 1982, Cabelli et al., 1982; Cabelli, 1980; and Cabelli et al., 1979) and more recently by Brown (1983) and Seyfried et al. (1985a,b), provided a basic framework upon which to model the present study. Two specific goals of the present study were the improvement of the study design and the analytical techniques.

8.7.1 Prospective study design

Morbidity in swimmers has been investigated by retrospective, prospective, and cross-sectional methods (Chapter 2). Retrospective, or case-control, studies are useful for following disease outbreaks and for conclusively linking specific waterborne pathogens with outbreaks (Rosenberg et al., 1976; Bryan et al., 1974). Only very rarely do retrospective studies provide accurate water quality information at the time of exposure (Cabelli et al., 1979), and generally, this information is limited to

certain pre-specified ailments (Lilienfeld and Lilienfeld, 1980), and the information collected may be subject to biases arising from the recall of past events, after the disease process has already been established overtly (Abramson, 1979). A prospective study can reveal the water quality at the time of exposure, the extent and type of disease transmitted, and can provide a direct estimate of the risk of acquiring a disease for the exposed subject (Lilienfeld and Lilienfeld, 1980). However, prospective studies are more expensive and difficult to undertake than are retrospective studies (Lilienfeld and Lilienfeld, 1980). Prospective studies require large study populations to attain statistical significance, and are quite inefficient in studying more rare diseases, and participation in them may influence disease development (Lilienfeld andLilienfeld, 1980). Alternatively, in a cross-sectional study, prevalence, rather than incidence of illness is usually determined, although it is easier and more economical to undertake than either prospective or retrospective studies (MacMahon and Pugh, 1970). However, cross-sectional studies do not establish the temporal sequence of events needed for many causal inferences (Mausner and Kramer, 1985). Incidence rates can be obtained in a prospective investigation, and the follow-up time factor can be reduced to exclude a number of illnesses with long term incubation periods.

In summary, it is clear why a prospective control study design was preferable for this investigation.

8.7.2 Exposure categories and definitions

In this study, there were three categories designated for water exposure (i.e: swimmers, waders, and persons who did not go into the water) in contrast to those of Cabelli and his colleagues (Dufour, 1985 in draft; Cabelli et al., 1982; Dufour, 1982; Cabelli, 1980; and Cabelli et al., 1979) and Seyfried et al. (1985a,b). The purpose of using three categories of water exposure was to determine if dose-response effects could be detected.

Cabelli and his associates (1982) defined a swimmer as a person who completely exposed their head to the water, that is, who immersed their head in the water, and all other persons were classified as nonswimmers, whether or not they went into the water. Problems of the following nature can arise from such criteria:

1. Reporting of head immersion by a contact or spokesperson may not be accurate for other beach group members (Seyfried et al., 1985a,b) than themselves.
2. Other different types of swimming-related illness may ensue from exposure to microbes which may be associated with routes of entry other than those associated with head immersion (e.g through a wound, cut, or skin abrasion), and associated water ingestion (Cabelli et al., 1982). Furthermore, although a person might not immerse their head, they may be exposed to microbes in the water if they were splashed (e.g: J.S. Bell, pers. comm.). Thus, the

nonswimmer control population of Cabelli and his colleagues might be inappropriate because abnormally high morbidity rates could result, and might not be representative or reflective of the background morbidity rates. Accordingly, the morbidity rates of swimming-related illness could be somewhat conservative.

Thus, the definition of a swimmer, presumably, was much improved when Brown (1983) defined a swimmer as any person who entered the water (i.e: any exposure to the water). In the present study, persons who did not enter the water beyond knee-depth, at maximum, were designated as waders. Swimmers were persons who entered the water beyond knee-depth. Some bias might arise if contact persons misclassified swimmers and waders. However, at the time of the initial interview, the difference between the two categories was emphasized to all study participants. Contact persons were made aware of their responsibilities in this regard, particularly, and definitions were re-iterated at the time of the follow-up. In addition, clues such as wet bathing suits, hair, arms, or upper legs were found to be useful.

8.7.3 Contact persons

In this study, contact or spokespersons were appointed for obtaining follow-up information due to the large number of persons involved in the study, economic and time constraints, and because some subjects were too young to

provide information about themselves. Contact persons would likely provide more accurate information about themselves than those who were not contact persons, and would probably tend to report illness more frequently and accurately for themselves. For these reasons, whether or not the subject was a contact persons was considered in the analysis. Both Cabelli and his colleagues (op. cit.) and Seyfried et al. (1985a,b) also used contact persons to obtain follow-up information, but only Seyfried et al. (1985a,b) considered this factor in their analysis. A possibly difficulty, not considered in the present study, is that contact persons who were mothers of other beach group members for whom they reported follow-up information, or who lived with these others, might report more accurately for the others than those were not in such categories, and the sex of the contact person might also be important since females might report follow-up information accurately. However, although this information was collected, it was necessary to limit the number of factors included in the analysis to a reasonable number and set priorities (D.F. Andrews, pers. comm.).

8.7.4 Interviewers

The fourteen interviewers used in the present study were male and female students of university age, without prior interview experience. Interviewers were paid minimum wages, plus a commission for all completed interviews. Some

investigators have indicated that it may be best to employ females, particularly those in their late thirties or early forties, with grown families, without medical or other interview experience, as interviewers because subjects tend to trust such persons more easily, and provide more accurate follow-up information (J.D. Burch, pers. comm.). In this study, economic factors prohibited the employment of older persons. Improvements in data quality might have ensued if female interviewers had been employed, and if fewer interviewers, who were industrious and perhaps better paid, had been utilized.

Neither Cabelli nor his associates (op. cit.), nor Seyfried et al. (op. cit.) considered interviewer in their analysis. No discussion was provided by Seyfried et al. (op. cit.) for this omission, whereas Cabelli and his associates (op. cit.) were clearly not in a position to consider this variable.

In this study, despite the uniform training and on-going monitoring of interviewers, it was felt that discrepancies in the reporting of information could be produced between the different interviewers.

8.7.5 Microbial sampling regimes and sample frequencies

Concern has arisen in the present study regarding whether or not the bacterial and viral sampling regimes and frequencies used provided an accurate assessment of bathing water quality with which to relate reported illness

(Section 8.5 and 8.6). Future investigations must address such problems and consider the establshment of standard regimes (Section 8.5). Recall that Cabelli and his associates (Cabelli _et al_., 1982) collected three to four surface water samples at two or three sites from each beach and Seyfried _et al_. (1985a,b) usually collected one water sample from each beach twice daily.

8.7.6 Beach

Beach was a factor considered in the present analysis because of various potential differences, other than bacterial density, between locations (e.g: sources of pollution). Neither Cabelli and his group (op. cit.), nor Seyfried _et al_. (op. cit.) considered the importance of beach in their analysis.

8.7.7 Socioeconomic status (SES)

SES assessment, in this study, was only crude, based upon an assessment developed by Cabelli _et al_. (1979), and probably could be improved upon. However, direct ascertainment of income from subjects is not recommended due to its potentially offensive reception on the beach, and thus potential loss of study participants or even interviewers might ensue. Incidentally, Cabelli and his associates did not include this factor in their analysis, whereas Seyfried and her colleagues (1985a,b) did consider

this factor.

8.7.8 Swimming before or after the interview day

The possibility of water exposure at locations other than where the subject was interviewed was considered for four days prior to, and three days subsequent to being interviewed at the beach. This period of investigation for alternate water exposure was selected because it was considered to be an appropriate period for the detection of many swimming-related infections (Brown, 1983), was at least as long as the period of follow-up, and has also been used in previous studies (e.g: Seyfried _et al_., op. cit.). Swimming before or after was included as a separate variable in the analysis and in the analysis of Seyfried _et al_. (op. cit.). However, the Cabelli group (op. cit.) did not include this factor in their analysis, instead, they excluded subjects who swam at other locations on either weekend day or who swam in the five midweek days, before and after, the weekend of interest (Cabelli _et al_., 1982). Exclusion of subjects was avoided in the present study.

Although the subjects were not specifically asked if they swam elsewhere on the interview day, the nature of the question regarding this particular factor provoked them to provide such information.

8.7.9 Period of follow-up

A three-day follow-up period was selected in order to obtain reliable and recallable information, to exclude illnesses with long-term incubation periods (refer to Brown, 1983, Table 8.2), which might have their origin in places other than at the beach, and thus to avoid the problem of excessive numbers of potentially confounding variables, to avoid person-to-person transmission of disease within a household, to avoid confusion which could result if the period coincided with the following weekend interviewing period, and for consistency with the previous studies conducted by Seyfried et al. (1985a,b). It was felt that many swimming-related ailments should have been detected, and distortion of the results by illnesses acquired in other settings should have been mainly avoided (Brown, 1983). The Cabelli group (1982) utilized a seven day follow-up period which might have resulted in the detection of some cases transmitted from person-to-person and some cases whose origin was not related to swimming.

8.7.10 Symptomatology

Morbidity was followed, and reported by contact persons. This style of reporting could have introduced subjective differences, such that misclassification of symptom, and symptom-related information, could result. The lack of quality control on the diagnosis and disease reporting stage (R.F. Lacey, pers. comm.) was a problem in this study, as well as those of the Cabelli group (1982)

and Seyfried et al. (1985a,b). No effort was made to display the link between indicator density and disease outcome via any actual causative agents responsible for swimming-related illnesses, and this resulted in a weakness in the study, only partially supported by statistical inference, according to Lacey (pers. comm.). The reasoning for the lack of clinically-confirmed symptoms by physicians, as well as confirmed laboratory isolations, where possible, was that the study population was extensive in size, and lived in many different regions, such that the labour and time involved would be prohibitive. However, it remains to ascertain whether this might be effective in a smaller survey more restricted in area. It appears that the importance of swimming-related illness might be properly assessed in a smaller cohort, if the work of Seyfried et al. (1985a,b) is considered representative. Further investigation is warrented in this area. Presumably, more credibility and confidence in the study results would ensue if such practices were instituted.

A crude attempt was made in this and the previous study (Seyfried et al., 1985a,b) to determine the severity of reported symptoms, by determining if the subject stayed home, the duration of the period spent at home, and whether or not he or she saw a physician. The Cabelli group (1982) abandoned the use of confirmed medical reports early in their study, and instead, utilized their "highly credible" symptom classifications, yet another crude index of severity of reported symptoms.

8.7.11 Chemical and biotic pollution

In no way was the impact of reported symptoms in this study related to: 1) the exposure to chemicals in the water samples, 2) other microbes not considered, or 3) other biotic effects in the water samples tested (refer to Tables 1.1 and 1.2, and also, toxic algae, etc; Ministry of National Health and Welfare, 1983), addressed (Cabelli, 1980) for any of the three studies under discussion.

Due to the media-generated concern about chemically-derived compounds (e.g. in our recreational waters and drinking waters), efforts to assess their effects is required in future investigations. At this time, the microbes examined in the recreational water samples tested were felt to be those most relevant in recreational water quality assessment.

8.7.12 Types of bias

Sackett (1979) catalogued an extensive list of biases which might occur in the sampling and measurement stages of analytical research. It is appropriate to consider some of the biases which might arise from the epidemiological design of the present investigation. A detailed list of other potential biases was published by Sackett (1979).

Non-respondent bias might have occurred in the study, such that, non-respondents from a specified sample could

display exposures or outcomes which differ from those of the respondents (Sackett, 1979). This bias can distort the relative odds in either direction, and serves as a stimulus to achieve respondance rates in excess of 80% (Sackett, 1979). Because a very acceptable response rate of 90.4% (9296 out of 10287 interviews) was achieved in this study, this bias was not a major concern. Furthermore, the number of persons to refuse an interview was small (991 out of 11278, or 8.8%).

Membership bias could have resulted in this study, such that membership in a group (e.g: beach-goers) might imply a degree of health which differs systematically from that of the general population (Sackett, 1979). As a result of this bias, the relative odds might be influenced in either direction. Thus, the results of the present study apply to the beach-group population studied, and not necessarily to the general population.

Diagnostic suspicion bias was considered an important possibility in this investigation, that is, a knowledge of the subject's exposure to a putative cause (i.e: a wader or swimmer being exposed to the water) might affect the intensity and outcome of the diagnostic, or follow-up, process, and this bias can spuriously increase the relative odds (Sackett, 1979). Hopefully, this bias was avoided by proper, uniform, and consistent interviewer training and monitoring.

Obsequiousness bias, whereby subjects may systematically alter questionnaire responses in the

direction that they perceive as desired by the interviewer (Sackett, 1979), might also have been avoided for the same reason as provided above. This bias could distort the relative odds in either direction (Sackett, 1979).

Expectation bias, such that observers may systematically err in measuring and recording observations so that they concur with prior expectation, could also distort the relative odds in either direction (Sackett, 1979). For the reasons presented above, it was felt that this bias was avoided.

Attention bias might have emerged in this study, such that study subjects might systematically alter their behaviour when they realize they are being observed, and thus distort the relative odds in either direction (Sackett, 1979). Although the interviewer training and monitoring procedures, hopefully, would have avoided this bias as well, it's existence is possibile in this study.

Misclassification of symptoms or water esposure status might have occurred in this study, such that estimates of relative risk could be biased (Schlesselman, 1982). However, random and independent errors tend to diminish the apparent degree of association between two variables, so that the odds ratio (or relative risk) is biased towards unity in two-by-two tables (Bross, 19854; Schlesselman, 1982). Existence of false positive or false negative symptom assessments, will result in a decreased estimate of relative risk, if such errors occur equally for exposed and unexposed subjects (Schlesselman, 1982). Errors in

ascertaining an individual's exposure status will also tend to attenuate the estimated relative risk if they occur equally in cases and controls (or in the ill and not ill; Schlesselman, 1982). If a true dose-response relationship exists which links exposure to symptom (or illness) development, random errors in exposure classification would not likely hide substantial risk increments (Marshall <u>et al</u>., 1981; Schlesselman, 1982). Generally speaking, the odds ratio, relative risk, or risk difference may be spuriously increased or decreased if classification errors depend either on outcome or exposure status (Schlesselman, 1982). Extensive efforts were made to avoid biases associated with such misclassifications, and have been been outlined in section 8.7.2.

8.8 <u>Demographic and other characteristics of the study population</u>

As mentioned previously (Chapter 5), preliminary analysis of the crude data revealed several important and significant associations between the three categories of water exposure and various factors. Multivariate analysis was employed to investigate the factors listed (except for headunder and swallow, for which reporting by contact persons was considered to be of marginal value, according to the responses at the time of interview.

The number of controls in this study (n=1193, or 14.2%) was reflected and limited by the number of persons

who chose not to enter the water during the hot summer days. This contrasted to the large number of swimmers (6653 or 79.0%).

It has been our experience in this and in previous studies (Seyfried et al., 1985a,b) that most persons who visit the beach either swim or wade. Note that 65.0% of the participants were waders or swimmers (i.e. entered the water) in the study conducted by Seyfried et al. (1985a,b). Cabelli et al. (1979) noted that two-thirds of the beach population in his study were swimmers, by their definition (Section 2.3).

This study is prospective in nature, and therefore observational. Accordingly, the investigator cannot control the numbers of persons who entered the water and those who do not (Lilienfeld and Lilienfeld, 1980).

The number of waders in this study was small (574 or 6.8%) when compared to the number of swimmers investigated. However, dose-response effects were detected in the crude data and control of the numbers of waders, once again, is beyond the scope of an observational study (Lilienfeld and Lilienfeld, 1980).

In conclusion, in prospective cohort studies, such as this, it is likely that the majority of the subjects will go into the water at the beach, and persons who do not enter the water will be fewer in number.

8.9 Crude morbidity data

The crude symptom rates are provided in Table 5.10 for the study population used in logistic regression modelling. As mentioned previously, they are quite comparable to the rates displayed by the entire study population, and thus the former will provide the basis for this discussion. The reader is referred to Chapter 5 for the specific details and a summary of the data.

For illness as a whole, that is, "overall illness", the crude symptom rate was: 76.8% per 1000 swimmers, 41.8 per 1000 waders, and 19.3 per 1000 persons who did not enter the water. For the combined waders and swimmers, 74.0 per 1000 persons became ill. This suggested that a dose-response effect existed in the crude data. The four highest observed crude symptom rates for illness investigated (i.e. not including overall illness), were:

1. Respiratory (32.5 per 1000 swimmers), gastrointestinal (21.6 per 1000 swimmers), other (14.9 per 1000 swimmers), and ear symptoms (9.6 per 1000 swimmers) in swimmers, (the remaining categories of illness were: eye, skin, allergy, and respiratory).
2. Respiratory and gastrointestinal (15.7 per 1000 waders), other (13.9 per 1000 waders), and ear, eye, and allergic symptoms (5.2 per 1000 waders), for waders. The remaining category was skin symptoms.
3. Respiratory and gastrointestinal symptoms (5.0 per 1000 people who did not enter the water), other symptoms (3.4 per 1000 persons who did not enter the water), and skin and eye symptoms (2.5 per 1000 persons who did not enter the

water), for persons who did not enter the water. The remaining categories were: ear and allergic symptoms.

Thus, respiratory and gastrointestinal symptoms figured predominantly in each category of water exposure, with a dose-response effect resulting, which suggested that swimmers were reportedly more ill than either waders, or persons who did not enter the water. It was not considered surprising that respiratory and gastrointestinal symptoms led the list, if one considers the probable importance of the potentially predominent viruses in the population as a whole, and in those exposed to recreational waters.

Deviations from this trend did exist. Waders tended to exhibit reported respiratory, gastrointestinal, eye, and ear symptoms in excess of persons who did not enter the water. This might reflect the misclassification of exposure. For example, the roles of splashing of water, fomites and other forms of indirect transmission of disease, as well as the possibility of a wader bending down and putting their hands in the water or even transferring microbes indirectly or by hand or otherwise, should be considered. Clearly there is a need to understand microbial routes of entering into the human body, in more detail.

Examination of the crude symptom rates revealed that significant differences at the 5% level or better, were detected between water exposure and reported: overall illness, respiratory, gastrointestinal, other, ear, skin, and eye symptoms, but not between water exposure and allergic symptoms. For all of these categories, except for

the skin category, the pattern of highest to lowest crude symptom rate was: swimmers, followed by waders, followed by persons who did not enter the water. Persons who did not enter the water had a slightly higher reported crude skin symptom rate than waders, but the magnitudes of these values were small.

Examination of the odds ratio data provided in association with the crude data, revealed that swimmers were at significantly elevated risk of becoming ill versus persons who did not enter the water, and all of the odds ratios were greater than 2.00, which indicated that the risk was large (the odds ratio for allergic symptoms was not significant, since the 95% confidence limits included 1.00).

For waders, significantly elevated risks of becoming ill (versus those who did not enter the water) were obtained for: other, gastrointestinal, overall illness, and eye symptoms (in each case, the odds ratio exceeded 2.00).

The crude symptom rate and odds ratio data for persons who entered the water versus those who did not was also provided in order to make comparison with the previous study of Seyfried _et al_. (1985a,b). For overall illness, the reported crude symptom rates were: 74.0 per 1000 people who went into the water, in contrast to 19.3 per 1000 people who did not go into the water. This compared favourably to the overall illness data collected by Seyfried _et al_. (1985a), where the rates were 69.6 and 29.5 per 1000 persons, respectively. However, it must be noted

that respiratory symptoms included fever in the studies undertaken by Seyfried et al (1985a,b), whereas fever was placed into the "other" category in this study. In this study, the four highest reported crude symptom rates observed for the specific categories of reported illness investigated, from the highest to the lowest, were:

1. Respiratory (31.1 per 1000 persons who went into the water), gastrointestinal (21.2 per 1000 persons who went into the water), other (14.8 per 1000 persons who went into the water), and ear (9.3 per 1000 persons who went into the water) symptoms, for persons who went into the water. For persons who went into the water, the remaining categories were: eye, skin, and allergy, respectively.
2. Respiratory and gastrointestinal symptoms (5.0 per 1000 persons who did not enter the water), other (3.4 per 1000 persons who did not enter the water), and skin and eye problems (2.5 per 1000 persons who did not enter the water), for persons who did not enter the water. The remaining categories were ear and allergy.

Thus, the respiratory and gastrointestinal categories figured predominantly in both exposure groups. Persons who went into the water were significantly more ill (at the 5% level, or better) than those who did not, for all categories of illness other than allergic symptoms. Examination of the odds ratio data revealed that persons who entered the water were all at significantly elevated risk of becoming ill (and all had odds ratios in excess of 2.00) for all the categories of reported illness (other

than allergic and skin ailments).

In order to ascertain whether the trends detected between swimmers, waders, and persons who did not enter the water, were genuine, and whether the risks were representative, logistic regression analysis was employed. The possibility of many potentially confounding variables existed, as well as the possibility of the effects of several factors other than bacterial count.

Despite the differences between studies, the crude data are consistent with the general findings of Cabelli and his coworkers (Dufour, 1985; Dufour, 1982; Cabelli _et al._, 1982; Cabelli, 1980; Cabelli _et al._, 1979) and Stevenson (1953) who found that swimmers more frequently became ill than nonswimmers. The results, herein, are in good agreement with Stevenson's (1953) investigation which detected appreciably higher illness incidences in the swimming group and found that eye, ear, nose, and throat ailments comprised more than half of the overall illness incidences. However, it is prudent to recall the differences between the studies (Chapter 2).

The crude symptom rate data appear in Table 5.11 for head immersion and water ingestion, by swimmers. Caution is advised in the interpretation of the data because reporting by contact persons about these factors was not of very good quality. In any case, the reported data suggested that swimmers who put their head under the water become significantly more ill (at the 5% level, or better) than those who did not put their head under the water only for

ear problems, and swimmers who swallowed water became significantly ill (at the 5% level, or better) versus those who did not swallow water, for respiratory, gastrointestinal, other, ear, skin, and eye ailments.

8.10 Logistic regression modelling

8.10.1 By wadeswim (for swimmers, waders, and persons who did not enter the water)

Consideration of the overall illness models (which contained greater numbers of ill persons versus the specific illness categories) examined generally revealed that swimmers were at significantly increased risk of becoming ill, whereas waders tended to be at lower risk, but the magnitude of their risk was somewhat debateable. Additionally, the models generated for the various types of illnessess (overall and specific) considered generally revealed that there was no evidence that the function of bacterial count, which took the three various water exposure categories into account, contributed to the prediction of reported illness. In fact, only the overall illness versus *P. aeruginosa* (on mPA) model attained borderline significance at the 5% level. Instead, several other factors proved to be far more important to the models, and thus to the prediction of reported illness, and included such factors as: age, contact person, and interviewer - all of which were always present in the

models, as well as: swimming before or after the interview day, beach, sex, and water exposure category (or wadeswim).

8.10.2 For swimmers only

In the logistic regression models generated for swimmers only, there was a general overall tendency for a lack of evidence to suggest that the bacterial count contributed significantly to the prediction of reported illness in swimmers. Instead, almost every model included the common factors which were found in the above models, that is: age (apart from the eye versus total staphylococci model), contact person, and interviewer, and occasionally one or more of the following: sex, beach, and swimming before or after the interview day.

8.10.3 Implications of logistic regression modelling

The findings from the overall illness models that swimmers generally tended to be at significantly increased risk of becoming ill were valuable. They imply that the cause(s) of the increased risk merit investigation since the risk was related to swimming but was not precisely constrained in the models generated. From these same models it was also apparent that waders were at lower risk than swimmers (a dose-response effect) but the magnitude of their risk was debateable.

The primary concern arising from the entire data is

whether or not the bacterial count really is important in the prediction of illness in swimmers. In order to examine this in more detail as well as other relevant factors, the discussion will focus upon the models for swimmers only.

Clearly, it was essential to examine the quality of the data, including the possible sources of error involved in the study. In general, logistic regression modelling of data for the swimmers revealed that reported illness increased as the bacterial counts increased, but the increase was not significant at the 5% level.

Firstly, the most important factors to all the logistic regression models generated, which were: age, contact person, and interviewer. It was not surprising that age figured predominantly in the models because it might reflect a variety of contributing factors which might be important in the aetiology of swimming-related illness. The age of a swimmer might reflect such factors as: the general immune status of the subject (i.e: younger persons may be at increased risk of illness because they have not had prior exposure and gained immunity to some specific pathogenic microbes which might be acquired during swimming), the frequency and duration of swimming exposure (i.e: younger persons might swim more often and for longer periods of time than older persons, and thus perhaps prolong and increase their exposures), and the role of physical exertion (i.e: younger swimmers might be under greater body stress as a result of more strenuous physical exertion, in contrast to older swimmers). Some or all of

these factors might prove to be quite important in the prediction of reported illness in swimmers.

Contact persons, as expected, tended to report illness more frequently than persons who were not contact persons, and were also quite important to the models generated. It is suspected that the utilization of contact persons in studies of swimming-related illness would produce similar results. Previous experience, in our own laboratory, has confirmed their importance (Seyfried et al., 1985b).

The interviewer effect was also a very important factor in the models generated. Despite persistent and extensive training, and quality control efforts to avoid interviewer effects, their inclusion was quite necessary in the models produced. Consequently, an interviewer bias in the data was avoided. Interestingly, previous investigations in this laboratory did not considered this variable (e.g: Seyfried et al., 1985b).

The present investigation exposed the issue of the role of specific age, contact person, and interviewer in previous studies of swimming-related illness. Cabelli and his colleagues (Dufour, 1985 in draft; Dufour, 1982; Cabelli et al., 1982; Cabelli, 1980; Cabelli et al., 1979) have not adequately addressed and considered the possibility of biases arising from such sources. Previous investigations by our laboratory (Seyfried et al., 1985a,b), too, have not examined the effects of specific age and interviewer, in the data. As a result, their findings regarding the importance of bacterial count in the

prediction of swimming-related illness may be in question.

It has also been postulated by our laboratory that one possible aetiology of swimming-related illness might be the trauma of entering the water, that is, the change from air to water temperature might produce a stress upon the body which increses individual susceptibility to infection. Examination of this hypothesis requires further experimental and observational testing.

The microbiological methods employed in this study raise a number of important issues. It is not known whether the collection of two water samples per day accurately represents the water quality at a particular beach. Unfortunately, the lack of universal sampling criteria prohibit close comparison between studies. In addition, the value of alternative recreational fresh water quality bacterial and viral indicators, and pathogens, not considered in this investigation, in the prediction of reported swimming-related illness, is unknown and merits further investigation.

Other sources of pollution which were not considered in this investigation (e.g: chemical) might also prove to be of great value in the prediction of swimming-related illness.

Also, the possibility remains that many other factors might also prove valuable in the prediction of swimming-related illness.

The possibility remains that the linear models used to predict swimming-related illness thus far were too

simplistic and require modification to exponential or polynomial function models.

The findings of this study lead one to focus upon a number of very important issues in future investigatons. Whether or not bacterial count is important is really unknown at present. It is possible that the importance of bacterial count was reduced by the presence of more important factors. However, the possibility remains that factors such as: immune status, duration and frequency of water exposure, physical exertion, and general bodily constitution, might play a predominant role in swimming-related illness.

Immune status is difficult, but not impossible, to assess in a prospective study, if the efforts are concentrated. Duration and frequency of water exposure and physical condition are both difficult to assess in prospective situations, by our experience (and would be even more frustrating in a retrospective setting), but require much more attention. General body constitution and condition necessitate greater medical participation in observational studies.

In summary, a large number of potentially important variables might influence the prediction of reported swimming-related illness. A great deal of further investigation is required in order to assess their impact and ascertain their importance. In past, studies of swimming-related illness have been rather simplistic, and as such, the role of bacterial count has proven difficult

to evaluate. Certainly, greater specificity is a requirement for future studies of this nature.

Due to the nature of the problems incurred in this study, it may prove valuable for future investigators in prospective studies to:

1. Reduce the study population sample size (e.g: n=2000).
2. Interview each subject individually during follow-up, in a home setting.
3. Confirm symptomology via study physicians and laboratory testing.
4. Interview subjects in a specific age group (e.g: 10 to 20 years-of-age).
5. Employ a small number of interviewers (i.e: one or two) who are female, and preferably aged 40 to 45, and are of non-medical background.

8.10.4 Comparisons between studies

Comparisons between studies of swimming related illness prove to be rather difficult due to the major differences in both microbiological and epidemiological methodologies. Consider the results presented for the freshwater studies conducted by Dufour, a member of Cabelli's group (e.g: Dufour, 1985, in draft; Cabelli _et al._, 1982; 1979; Seyfried _et al._, 1985a,b), and the present investigators in this study - all of which generated predictive models of reported swimming-related illness, in one form or another. The methodological differences between

Table 8.1 Differences between the Present Study and That of Seyfried *et al.* (1985a,b).

FACTOR	PRESENT STUDY	PREVIOUS STUDY (Seyfried *et al.*, 1985a,b)
Water-exposure categories	Three categories: swimmers, waders, and persons who did not enter the water.	Two categories persons who entered the water, and those who did not enter the water.
Follow-up	Telephone only	Telephone, mail, and phone-mail, but only first used due to bias problems
Definitions of illness	Same as previous study, but fever no longer in respiratory category, now placed in "other" category.	
Logistic regression	Used FUNCAT.	Used GENSTAT.
	More confounding variables were considered.	Only contact person, age category, sex, swimming before or after, were used.
	Used all data.	Used data when 50 or more swimmers were on the beach.
Water sampling	Twice daily.	Varied up to three times daily.
Bacteriology	same except:	
	a). Only surface water tested.	Surface water and sediment tested.
	b). *P. aeruginosa* enumerated by MF on MPA and MTIN.	*P. aeruginosa* enumerated ny MPN.
	c). Fecal streptococci enumerated by MF.	Fecal streptococci enumerated by MF and MPN.
	d). Enterococci enumerated.	Enterococci not enumerated.

the present study and those of the Cabelli group were presented in Chapter 6. The differences between the studies of Seyfried *et al*. and the present investigation are presented in Table 8.1. It is useful to list the equations used to predict reported swimming-related illness which arose from the three studies. However, it must be emphasized that direct comparisons are difficult and may be dangerous, given the microbiological and epidemiological methodological differences.

From the investigation undertaken by Dufour (1985, in draft), who used only simple linear regression to predict swimming-related illness, the following two equations were generated and gave equivalent results when the enterococci and *E. coli* were examined, with respect to the strength of their relationship to swimming-related gastroenteritis (note that bacteria considered in these models included: the enterococci, *E. coli*, *Klebsiella* sp., *Enterobacter* sp., *Campylobacter* sp., total coliforms, *C. perfringens*, *P. aeruginosa*, fecal coliforms, *A. hydrophilia*, and *V. parahaemolyticus*:

$$1)\ y = -6.28 + 9.40 * \log_{10}x \ .....(1)$$

and,

$$2)\ y = -11.74 + 9.40 * \log_{10}x \ .....(2),$$

where x was the geometric mean density per 100 mL of water

for the enterococci in the first model and for E. coli in the second model, and y was the swimming-associated illness rate per 1000 swimmers (recall that subtraction of nonswimmer background illness rates occurred - see Section 2.3).

From the logistic regression modelling done by Seyfried et al. (1985a,b), the three following equations were presented for the prediction of illness in swimmers (note that models considered were: total illness versus staphylococci in water (chi-square p-value <0.001), skin problems versus total staphylococci in water ($p=0.044$), eye ailments versus total staphylococci in water (in swimmers with head under the water), ($p=0.002$); total illness versus fecal coliforms ($p<0.001$)) and fecal streptococci ($p=0.016$) in water versus total illness, total illness versus P. aeruginosa in sediment ($p=0.36$), and gastrointestinal illness versus fecal streptococci ($p=0.069$) in water):

1) $\log_{10}(p/1-p)=-2.65+0.696\log_{10}$total staphylococci per 100 mL of water

$$r=0.439,$$

for the total illness versus total staphylococci model which also considered the age group and contact person,

2) $\log_{10}(p/1-p)=-1.4441+0.18177\log_{10}$fecal coliforms per 100 mL of water

$$r=0.284,$$

for the total illness versus fecal coliform model which also took into account the age group and contact person, and

3) $\log_{10}(p/1-p)=-1.302+0.11753\log_{10}$fecal streptococci per 100 mL of water

$$r=0.166,$$

for the total illness versus fecal streptococcal model which also took into account age group and contact person.

The bacterial indicators, isolated from surface waters, found to correlate best with swimming-associated morbidity were total staphylococci, fecal coliforms, and fecal streptococci. Finally, total staphylococci, along with fecal coliforms or *E. coli* were recommended for investigation as indicators of swimming associated health risk.

In the present study, the four best models based on the chi-square p-value from logistic regression modelling (Section 7.5), for the prediction of illness in swimmers were outlined in Section 7.5, and were:

1) $\log_{e}(p/1-p)=-4.752+0.347\log_{10}$geometric mean of the fecal coliform count

(chi-square p-value=0.088 for the count)

for the GI illness versus fecal coliform model which also took into account: age, contact person, and interviewer,

$$2)\ \log_e(p/1-p)=-6.044+0.560\log_{10}\text{geometric mean of the staphylococcal count}$$

(chi-square p-value = 0.0947 for the count),

for the skin problems versus total staphylococcal model, which also considered: age, contact person, and interviewer,

$$3)\ \log_e(p/1-p)=-4.671+0.325\log_{10}\text{geometric mean of the } \underline{E.\ coli} \text{ count}$$

(chi-square p-value=0.1021 for the count),

for the GI illness versus E. coli model, which also took into account: age, contact person, and interviewer, and

$$4)\ \log_e(p/1-p)=-2.658+0.182\log_{10}\text{geometric mean of the } \underline{P.\ aeruginosa} \text{ count (on mPA)},$$

(chi-square p-value=0.1237 for the count),

for the overall illness versus P. aeruginosa model, which

also included age, contact person, interviewer, beach, and swimming before or after.

In this study, there was no evidence to suggest that the bacterial count contributed to the prediction of reported illness in swimmers, in these models - and whether or not this finding is genuine, or an artifact of the swamping-influence of other criteria merits further serious investigation. In addition, the results from the study suggest that the following be employed as bacterial recreational fresh water quality indicators: fecal coliforms (and *E. coli* if desired), total staphylococci, and *P. aeruginosa* on mPA.

8.11 Bacterial guidelines for fresh recreational waters and associated matters

8.11.1 United States

In January of 1986, the United States Environmental Protection Agency issued a document concerning ambient water quality criteria for bacteria. In the document, the following ideas were presented and were based largely on work undertaken by the Cabelli group (Dufour, 1985 in draft.; Dufour, 1984; Cabelli *et al.*, 1982; Cabelli *et al.*, 1980).

1. For public beaches, more frequent bacterial sampling was recommended because increasing the number of samples improves the accuracy of bacterial water quality estimates,

and improves the likelihood of correct decisions about beach closure. Waters with more casual use require the examination of fewer samples due to the reduced population at risk.

2. Bacterial enumeration methods were deemed imprecise, and environmental conditions (e.g: rainfall, temperature, and wind) will vary in time and space.

3. Noncompliance with the criterion occurs when the maximum geometric mean is exceeded or when any individual sample exceeds a confidence limit, selected according to a level of swimming use. The mean log standard deviation for E. coli densities from nine freshwater beach sites which were studied was about 0.4. The mean log standard deviation for the enterococci in freshwater samples was also approximately 0.4 (and in seawater samples was approximately 0.7). The values 0.4 and 0.7 were used in calculations associated with proposed monitoring regimes and upper percentile values.

4. It was suggested that sampling frequency be related to the intensity of use of the water body. In areas of heavy weekend use, weekly samples collected in peak periods were deemed reasonable. In areas of less heavy use, biweekly or monthly samples might be adequate, according to the EPA. Generally, it was felt samples should be acquired in dry weather periods to set "steady state" conditions, but special studies might be necessary to evaluate the effects of wet weather conditions if sanitary surveys reveal that the area may be affected by storm water effects.

5. At present, the EPA is not recommending a change in the stringency of its recreational water bacterial criteria, such that the 1976 criteria (Section 1.6.3) remain in use (i.e: based on a minimum of five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log (geometric) mean of 200 per 100 ml, nor should more than 10 per cent of the total samples taken during any 30-day period exceed 400 per 100 mL. An alteration was not felt to be warranted until more information based on more experience with new indicators could be acquired. The EPA believes that it will take at least one triennial review and revision period for states to incorporate new indicators into State Water Quality Standards and start to gather experience with them.

6. Finally, consider what the EPA is investigating for the future. The EPA's evaluation of the bacterial data collected by the Cabelli group revealed that using the fecal coliform indicator group at the maximum geometric mean of 200 per 100 mL of water (U.S. Environmental Protection Agency, 1976) would cause approximately 8 illnesses per 1000 swimmers at freshwater beaches (and 19 illnesses per 1000 swimmers at marine beaches). These approximations were based on applying ratios of the geometric means of the various indicators from the EPA (Cabelli group) studies to the 200 per 100 mL fecal coliform criterion. The E. coli and enterococci criteria are presented in Table 8.2 and were developed using these currently accepted illness rates. The equations were

developed by Dufour (1983; 1985 in draft), and Cabelli (1983; Cabelli et al., 1982; Cabelli, 1980) and were used to calculate the geometric mean indicator densities corresponding to the accepted gastrointestinal illness rates. The densities were for steady state dry weather conditions. A beach is considered to be in noncompliance with the criteria if the geometric mean of several bacterial density samples exceeds the value found in Table 8.2. Noncompliance is also heralded by an unacceptably high value for any one bacterial sample. The maximum acceptable bacterial density for one sample is set higher than that for the geomeytric mean to avoid unnecessary beach closings due to single samples. To decide whether a beach should remain open, the long term geometric mean bacterial density is important. To set the single sample maximum, it is necessary to specify the desired chance that the beach will remain open when the protection is acceptable (and this chance or confidence level was based on EPA judgement). Single sample maximum densities for several confidence levels were calculated and the EPA then assigned qualitative use intensities to these levels. A low confidence level (75%) was assigned to designated beach areas. Table 8.2 summarizes the calculation results. Single sample maximum levels should be recalculated for individial areas if significant differences in log standard deviations are evident. The levels displayed in Table 8.2 depend on the assumed standard deviation of log densities and the selected level of acceptable risk. In Table 8.2, the limit

Table 8.2 Criteria for Indicator for Bacteriological Densities

	Freshwater enterococci	Freshwater *E. coli*	Marine water enterococci
Acceptable swimming associated gastro-enteritis rate per 1000 swimmers	8	8	19
Steady state geometric mean indicator density	33(1)	126(2)	35(3)
Designated beach area (upper 75%C.L.)	61(4,5)	235(4,5)	104(4,5)
Moderate full body contact Recreation (upper 82% C.L.)	89(4,5)	298(4,5)	158(4,5)
Lightly used full body contact recreation (upper 90% C.L.)	108(4,5)	406(4,5)	276(4,5)
Infrequently used full body contact recreation (upper 95% C.L.)	151(4,5)	576(4,5)	500(4,5)

Table 8.2 Continued

Notes:

(1) Calculated to nearest whole number using the equation:

mean enterococci density =exp10((illness rate/1000 people+6.28)/9.40)

(2) Calculated to nearest whole number using the equation:

mean E. coli density = exp10((illness rate/1000 persons+11.74)/9.40)

(3) Calculated to the nearest whole number using the expression:

mean enterococci density=exp10(illness rate/1000 people-0.20)/12.17)

(4) Single sample limit=exp10(A+B*C) where,

A - $\log_{10}$ indicator geometric mean density/100 mL

B - Factor determined from areas under the Normal probability curve for the assumed level of probability

C - Log_{10} standard deviation.

The appropriate factors for the indicated one sided confidence levels are:

75%C.L. - 0.675
82%C.L. - 0.935
90%C.L. - 1.28
95%C.L. - 1.65

(5) Based on the observed log standard devaitions during the EPA studies: 0.4 for freshwater E. coli and enterococci; and 0.7 for marine water enterococci. Each jurisdiction should establish its own single sample minimum levels if significant differences in log standard deviation occur.

Table 8.2 continued

EPA Criteria for Bathing (Full Body Contact) Recreational Waters

FRESHWATER
Based on a statistically sufficient number of samples (generally not less than 5 samples spaced over a 30-day period), the geometric mean of the indicated bacterial densities should not exceed one of the other of the following (1): *E. coli* 126 per 100 ml; or enterococci 33 per 100 ml; no sample should exceed a one sided confidence limit (C.L.) calculated using the following as guidance: designated bathing beach 75%C.L. moderate use for bathing 82%C.L. light use for bathing 90%C.L. infrequent use for bathing 95%C.L. based on a site-specific log standard deviation, then using 0.4 as the log standard deviation for both indicators

MARINEWATER
Based on a statistically sufficient number of samples (generally not less than 5 samples spaced over a 30-day period), the geometric mean of the enterococci should not exceed 35 per 100 ml; no sample should exceed a one sided confidence limit (C.L.) calculated using the following as guidance: designated bathing beach 75%C.L. moderate use for bathing 82%C.L. light use for bathing 90%C.L. infrequent use for bathing 95%C.L. based on a site-specific log standard deviation, then using 0.7 as the log standard deviation for both indicators

Note (1) - Only one indicator should be used. The Regulatory agency should select the appropriate indicator for its conditions.

for the measured geometric mean is ascertained directly from the regression equation relating illness to bacterial density, without any confidence level allowance for random variations in the geometric mean of several samples. A detailed protocol is available from the EPA (Goldberg, 1981) which shows how to ascertain the confidence level associated with an illness risk, once a maximum has been set for single samples. Note that more detailed background information for these data appear in Tables 2.2 and 2.3. The major criteria limitations were considered to be that the observed relationship may be involved if the population contributing fecal wastes becomes too small or if epidemic conditions prevail in a community.

7. With regard to the potential new future indicators, E. coli or the enterococci may be used for freshwaters, but only the enterococci are recommended for marine waters.

8.11.2 Province of Ontario and Canada

The Canadian and Province of Ontario microbial guidelines have been listed previously (Sections 1.6.4, 1.6.5, Table 1.6). However, the Canadian guideline was a geometric mean of 200 fecal coliforms per 100 mL of water (based on not less than five samples over 30 days, and resampling was advocated when any sample exceeds 400 fecal coliforms per 100 mL of water - The Ministry of National Health and Welfare, 1983). For Ontario, the guidline was a fecal coliform geometric mean density of 100 per 100 mL of

water (where at least ten samples per month and ten samples per location were recommended - Ontario Ministry of the Environment, 1978).

The state-of-the-art in the development of microbial guidelines for fresh recreational waters in Canada is not as developed as that in the United States. Development of guidelines will be based upon the need for public health officials to examine and assess, in detail, the results of this particular investigation. Perhaps an evaluation of the data and results presented in this thesis may enable officials to better understand the factors involved before new guidelines are considered. Should these officials establish the level of acceptable illness risk, then more specific guidelines could be outlined.

Pending further discussion of the results of this study, and further investigations in other regions, a conservative approach towards microbial guidelines is suggested. However, it is clear from the logistic regression models that the existing Ontario guidelines are more effective in the prediction of illness than the American or Canadian guidelines. The basis of this selection is attributed to the following:

1. Logistic regression testing of the Ontario and U.S. (and Canadian) guidelines.

2. Logistic regression modelling in swimmers for various illness-bacteria combinations.

3. The guideline is currently in existence in Ontario.

If one selects a guideline value of 100 fecal coliforms per

100 mL of water, then the equations derived from logistic regressions (Chapter 7) can be used to determine the percentage of ill swimmers. For example, inthe gastrointestinal illness - fecal coliform model:

$$\log_e(p/1-p) = -4.752 + 0.347\log_{10}\text{geometric mean of the fecal coliform count},$$

approximately 1.7% of the swimmers would be expected to become ill. Thus, we would be accepting 17 illness (+/-2*0.2) per 1000 swimmers, and not eight as recommended by the EPA for freshwater. Note that in order to achieve the value of eight, for which no adequate argument has been presented, and no reasoning for its universal application, the guideline value would not lie on this line. In addition, should one wish to use E. coli as an indicator and employ the equation:

$$\log_e(p/1-p) = -4.671 + 0.325\log_{10}\text{geometric mean of the } \underline{E}.\ \underline{coli}\ \text{count},$$

at a geometric mean of 100 (per 100 mL of water), 1.8% (+/-2*0.2), or 18 swimmers would be expected to become ill with GI problems, and reduction of this to the level of eight illnesses per 1000 swimmers would, once again, not cross the fitted line from this study.

Direct comparison with the EPA group is not possible for reasons of epidemiological and microbiological

methodological differences, and clearly the study populations may be different. Thus, it is recommended that the existing Ontario fecal coliform guideline be employed. (An E. coli guideline of 100 per 100 mL of water may be used, if desired, at present since the level of acceptable risk increased marginally).

It remains for public health officials to evaluate these data, as well as the other two equations presented in Section 7.5.8. For the logistic regression model for skin problems versus the total staphylococci, i.e:

$$\log_e(p/1-p) = -6.044 + 0.560\log_{10}\text{geometric mean of the total staphylococcal count},$$

at a geometric mean bacterial count of 100, 0.7% (+/-2*0.3) of the swimmers would be expected to become ill with skin ailments. It remains for public health officials to decide whether such minor ailments require guidelines. More importantly, the logistic regression model for overall illness versus P. aeruginosa yielded this equation:

$$\log_e(p/1-p) = -2.658 + 0.182\log_{10}\text{geometric mean of the } P.\ aeruginosa \text{ count},$$

where 7% (+/-2*0.1) of the swimmers would be expected to become ill at a grometric mean density of only one P. aeruginosa. It should be investigated whether the fecal coliform (and E. coli guidelines could be used in

association with the presence of *P. aeruginosa* to herald health problems.

8.12 Summarizing Remarks

The results of, and issues presented in, this study merit the following comments:

1. In general, closure of the beaches investigated during the summer of 1983, had no significant effect on the bacterial counts which were monitored.

2. The overall (i.e: for open and closed beaches, collectively) fecal coliform geometric mean data (i.e: 432) for both the open (423) and closed (453) study beaches exceeded the Ontario guideline value of 100 fecal coliforms per 100 mL of water (Ontario Ministry of the Environment, 1978).

3. A major concern in the area of bacterial recreational (both marine and fresh) water quality assessment is the lack of consistent and precisely defined sampling regimes, and isolation techniques, as well as the ambiguity and misaplication in the literature of the statistical procedures adopted for data presentation. It is imperative to assess:

a). Whether or not a series (with precise determination of number) of water samples should be collected at any one sample time,

b). Whether or not water sample(s) should be collected at specific time(s) of day,

c). Whether or not collection of water sample(s) should be undertaken at several times per sample day,

d). The importance of the day of the week in sample collection, and in relation to the above points,

e). The role of meteorological conditions (e.g: wet and dry conditions, wind, air and water temperatures) in all of the above points,

f). the role of bather density in all of the above points.

4. Further evaluation of the value of other bacterial fresh (and marine) water quality indicators and pathogens in relation to swimming-related illness should continue.

5. Further research is required in the area of virological isolation detection, and enumeration procedures from both marine and fresh (and marine) recreational waters, particularly in the area of the time periods required for each of these. Although enteric viruses have been of particular concern in relation to recreational water assessment, it may prove valuable to extend these horizons to include some viruses often associated with respiratory ailments as well (referral to public health data in a particular area may prove useful during the swimming season).

6. Crude morbidity data in this study (n=8420) revealed a general trend of greater morbidity in swimmers versus waders, versus persons who did not go into the water, in all categories of illness investigated, other than skin. For all categories of water exposure, respiratory and gastrointestinal ailments figured predominantly. For

overall illness, the crude symptom rates were: 76.8 per 1000 swimmers, 41.8 per 1000 waders, and 19.3 per 1000 persons who did not go into the water. For respiratory symptoms, these were: 32.5, 15.7, and 5.0 respectively. For gastrointestinal symptoms these were: 21.6, 15.7, and 5.0, respectively.

7. Logistic regression modelling (n=8420) foroveall illness generally revealed that swimmers were at significantly increased risk of becoming ill. There was no evidence to suggest that the function of bacterial count contributed to the prediction of illness. Instead, several other factors proved to be important in the prediction of reported illness (e.g: age, contact person, and interviewer which were always present, and one or more of: swimming before or after the interview day, beach, sex, and water exposure category).

7. Logistic regression modelling in swimmers (n=6653) revealed that the four best predictive illness models, based on the chi-square p-values, were:

a). GI illness versus fecal coliforms (p=0.0881),

b). Skin problems versus total staphylococci (p=0.0947),

c). GI illness versus E. coli (p=0.1021),

d). Overall illness versus P. aeruginosa on mPA (p=0.1237). Graphic presentation of these models are provided in Section 7.5.8.

8. In the logistic regression models generated for swimmers, there was a general overall tendency for a lack of evidence to suggest that the bacterial count contributed

significantly to the prediction of reported illness in swimmers. However, there was a general tendency that illness increased as the bacterial count increased. Instead, most models included: age, contact person, and interviewer, and occasionally one or more of the following: sex, beach, and swimming before or after the initial interview.

9. As a result of the logistic regression modelling in swimmers, it is important to ascertain whether or not particular bacterial counts are important in the prediction of illness in swimmers. Whether or not the trend observed is genuine or artefactual must be determined in future studies. These findings raise the possibility of previous investigators ignoring the effects of some potential counfounding variables (e.g: contact persons, interviewers, specific age. etc.). From the present study, whether or not the trend is real, for the bacteria investigated, cannot be concluded because it is necessary to determine:

a). The accuracy of current bacterial water sampling regimes and isolation techniques,

b). The value of other bacterial fresh water quality indicators, and pathogens,

c). The role of other possible sources of pollution (e.g: chemical),

d). Other factors which may be important in the prediction of illness (e.g: immune status, duration and frequency of water exposure, physical exertion, general body constitution),

e). Whether more sophisticated modelling techniques (e.g: exponential or polynomial) should be used.

10. It is recommended that future investigators consider the following when undetaking a prospective cohort study of swimming-related illness:

a). Reduce the study population sample size to a more managable number (n=1000 swimmers, and n=1000 nonswimmers would be adequate),

b). Interview each subject individually during follow-up, in a home setting,

c). Confirm symptomology in a study by utilizing physicians and laboratory testing,

d). Interview subjects in a specific age group (e.g: 10 to 20 years-of-age), and

e). Employ a small number of interviewers (i.e: one or two) who are female and preferably aged between 40 and 45, and do not have medical backgrounds.

11. Pending further investigation at present, it is suggested that the recreational water quality guideline in Ontario remain unchanged, that is, a geometric mean of 100 fecal coliforms per 100 mL of water.

12. Until further investigators recommend otherwise, the following be employed as recreational fresh water quality indicators: fecal coliforms (and E. coli, if desired), total staphylococci, and P. aeruginosa (on mPA).

CHAPTER 9

APPENDIX

9.1 Beach descriptions

9.1.1 Claireville Conservation Area (western tributary of Humber River, North Shore, Lake Ontario)

This dammed-up section of the Humber River is used for recreational sports which include swimming along the central western shore of the area. The sandy beach is long and narrow, and made up of sandy material. The roped-off swimming area is shallow, but deepens towards the centre of the lake.

The area is frequented by large organized groups. Washrooms are located at about 200 m from the beach. A cut grass and wooded park serviced by dirt roads surrounds the swimming area. Facilities include: swimming (with lifeguard supervision), boating, picnic areas, horseback riding, and fishing. Parking is provided 500m from the swim area. A charge is levied to enter the area. Wildlife includes a large number of Canada geese. A map of the area is shown in Figure 9.1

9.1.2 Boyd Conservation Area (Eastern tributary of the Humber River, North Shore, Lake Ontario)

Near to Claireville Conservation Area, and just south

of the town of Kleinburg is Boyd Conservation Area. A narrow sandy and stony beach with a roped-off swimming area are well sheltered by the surrounding trees and hilly countryside. The swimming area is fairly shallow (generally <1m) and the sediment is quite stony. Public facilities are located at 150m from the beach. During the 1983 season, the dam was removed, and presumably the area will not be open for public swimming in the future.

Large groups of people often visit the area. Italian ethnic majorities populate this area. A charge is levied to enter the area. Paved roads service much of the park. Facilities include: swimming (with lifeguard supervision), picnic areas, barbeques, and nature trails. A map of the area is given in Figure 9.2.

9.1.3 Albion Hills Conservation Area (main tributary of the Humber River)

This conservation area is located on the upper part of the Humber River (in contrast to Claireville and Boyd which are found at locations further south), north of the town of Bolton. The narrow sandy U-shaped beach is on the south-west margin of a lake from which the river exits. The roped-off swimming area is shallow for a long distance off-shore. The sediment is sandy. Public conveniences are located 50 m from the beach.

The Conservation Area is wooded and hilly, and is serviced by dirt tracks. A charge is levied to enter the

area. Facilities include swimming (supervised by lifeguards), picnicing, and fishing. A map of the area is given in Figure 9.3.

9.1.4 Heart Lake Conservation Area (Heart Lake)

This lake was produced by the daming of a natural depression in the drumlin-covered landscape. The depression is fed by a spring. The Conservation Area is located close to Brampton. There is a narrow sandy beach composed of sand. The swimming area is roped-off and the floor has a very clay-rich consistency. The swimming area drops-off in depth quite quickly. The lake is often the site of algal blooms.

The surrounding park is very hilly, and one descends from the surrounding car parks via a number of stairs to the beach and swimming area. A charge is collected for using the park. The toilets and other facillities are located adjacent to the beach, no more than 20m from the swiming area. Facilites at the park include picnic areas, swimming, fishing, and boating. A map of the area is given in Figure 9.4.

9.1.5 Kelso Conservation Area

The Kelso Conservation Area was acquired after the construction of a dam and lake on the western branch of Sixteen Mile Creek. The dam is an earth-filled structure

with a concrete spillway and spilling basin. Two gates on top of the dam regulate the water levels and flow rate. The reservoir, the Eden Lake, has a surface area of 85 acres, and a maximum depth of 35 feet. Kelso is a very popular recreational area, and visitors pay to enter. More than 200 acres of the Naigara escarpment are enclosed by the area.

A large sandy beach at the bottom of a steep escarpment is the main source of attraction. The swimming area drops off gradually. The public facilities are on the top of the escarpment over 500m from the beach (a hell of a long way to go for a leek). Facilities include: a changing house, snack bar, camping area, boating, and picnic areas. A map of the area is shown in Figure 9.5.

9.1.6 Professor's Lake

Professor's lake is located near the city of Brampton. It is a man made lake provided by an old gravel pit, now located in the centre of a new housing estate. The beach is narrow and sandy. The swimming area is roped-off, and drops of at first gradually and then very steeply at the edge of the old gravel pit. The area is kept very clean, and a chlorinated water shute is present (though clorination is limited to the shute, and the amount of chlorine entering the lake is trivial after dilution effects are taken into consideration). A charge is made to enter the beach and swimming area (under lifeguard supervision). The washrooms and snack-bar are at the edge of the beach, no more than 20

m from the water. A map of the area is given in Figure 9.6.

9.1.7 Authority to enter Conservation Areas to Conduct Studies

The Claireville, Boyd, Albion, and Heart Lake Conservation Areas are under the authority of the Metropolitan Toronto and Regional Conservation Authority. Kelso Conservation Area is under the authority of the town of Milton. Professor's Lake is under the authority of the city of Brampton.

9.2 *P. aeruginosa* modified mPA medium (Ontario Ministry of the Environment modified from American Public Health Association, 1981)

L-lysine monohydrochloride	5.0 g
Sodium chloride	5.0 g
Yeast extract	2.0 g
Xylose	2.5 g
Sodium thiosulfate	5.0 g
Sucrose	1.25 g
Lactose	1.25 g
Magnesium sulfate	1.5 g
Ferric ammonium citrate	0.8 g
Sodium desoxycholate	0.1 g
Phenol red	0.08 g
Agar	15.0 g

Distilled water (sterile)	800 mL

The ingredients, except for the agar, were added to a sterile beaker. The pH was adjusted to 7.6 and the agar was added. The mixture was heated to 93°C, until the agar started to dissolve. The mixture was not autoclaved. The mixture was cooled to 70°C (this was checked by determining the surface pH of 5mL of mPA in a small plate). The pH was adjusted, if required. The medium was cooled to 50 to 55°C (not higher than 60°C). Antibiotics, as listed below, were added, the resultant mixture was thoroughly stirred, and poured into petri dishes. The final surface pH was 7.1+-0.1.

Antibiotics:	Sulfapyridine	0.088 g
	Kanamyan sulfate	0.0085 g
	Nalidixic acid	0.037 g
	Actidione	0.15 g

The antibiotics were dissolved in 200 mL of sterile water, and heated gently to >50°C.

9.3 Modified Brucella (BNP) Broth

Brucella broth (Gibco) was supplemented with 0.2% $FeSO_4.7H_2O$ and autoclaved at 121°C. The broth was cooled to 55°C and supplemented with: vancomycin (15.0mg/L), trimethoprim (7.5 mg/L), polymyxin B (30,000 IU/L), sodium

bisulfate (0.025 per cent), and sodium pyruvate (0.05 per cent).

9.4 Enumeration and isolation of *Legionella pneumophilia* from water by the direct plating procedure (Canada Centre for Inland Water, ASTM task group D19:24:01:19 January, 1982)

Reagents and materials

Reagent grade chemicals were used.

Media preparation

1) pH reagents - A) 0.2 M potassium chloride
(14.91 g/L in reagent grade water)
- B) 0.2 M hydrochloric acid
(16.7 mL/L in reagent grade water)

Eighteen parts of A were mixed with one part of B. The pH of this mixture was checked against a pH 2.0 standard buffer. The mixture was dispensed into screw cap tubes in convenient volumes and autoclaved (at 121°C for 15 minutes).

2) Neutralizer - C) 0.1 M potassium hydroxide
(6.46 g/L in reagent grade water
though weight varies with reagent

purity).

10.7 mL of C was diluted with reagent grade water to yield 100 mL. This was dispensed into convenient volumes and autoclaved.

3) Buffered Charcoal Yeast Extract (BCYE) Agar (Pasculle etal., 1980)

Yeast extract	10.0 g
Norit SG charcoal or equivalent	2.0 g
Agar-agar	17.0 g
ACES buffer	10.0 g
(N-2-acetamido-2-aminoethane-sulfonic acid)	
L-cysteine hydrogen chloride	0.4 g
Soluble ferric pyrophosphate	0.25 g
Potassium hydroxide (1.0M)	40.0 mL
Reagent grade water	to 1000.0 mL

Antibiotic components:

Cephalothin	4.0 ug/mL
Colistin	16.0 ug/mL
Vancomycin	0.5 ug/mL
Cyclohexamide	80.0 ug/mL

ACES buffer must be hydrated as follows, in order to avoid possible yeast extract denaturation. Thus, 10 g of ACES buffer was added to 500 mL water and dissolved by

placing in a water bath (45 to 50°C). This solution was mixed with 440 mL water to which about 40 mL of 1.0 N potassium hydroxide was added. This mixture was used to hydrate the Noit SG charcoal (2 g), yeast extract (10 g) and the agar-agar (17 g). The resultant mixture was autoclaved, cooled to 50°C, and then the following were added separately: membrane filtered solutions of L-cysteine hydrogen chloride (0.40 g in 10 mL water) and soluble ferric pyrophosphate (0.25 g in 10ml water). The pH of the medium was adjusted to 6.9 at room temperature. Next, 0.4 u membrane filtered antibiotics were added and mixed. At least 20 mL per 15*100 mm petri dishes were then dispensed.

4) Tryptone Soya agar (BBL)

This was prepared as described and at least 20 mL per 15x100mm petri dishes were dispensed.

Sample Collection

A 1000 mL water sample was filtered through one or more membrane filters. Using a sterile 10 mL pipette, 10 mL of the sterile filtrate was removed and placed into an ointment jar. The membrane filter was placed into the ointment jar, bacteria containing side-down.

Sample processing

The capped ointment jar was placed into a sonic sink for 10 minutes, to dislodge the bacteria from the membrane filter. 1 mL of the filtrate-bacteria mixture was removed and placed into a capped test tube. 1 mL of pH 2.0 buffer was added.

Typically representative colonies were selected and transferred individually using a wire loop onto: 1) BCYE agar (for 37°C incubation), 2) BCYE agar (for 20°C incubation), 3) Typtone Soya agar (for 37°C incubation), and 4) Tryptone Soya agar (for 20°C incubation). The 37°C plates were incubated for 3 days, and the 20°C plates for seven days (note that plates can be divided into four to six sections to accomodate more colonies). Only those colonies which grew on BCYE agar incubated at 37°C were considered as potential Legionella pneumophila.

Calculation

The total number of Legionella pneumophilia per original sample was derived using the following formula:

$$T = N \times 10 \times A / B,$$

where T=the total number of bacteria per original sample volume, N= the number of typical colonies per plate, A=the total volume of pH heated sample, and B=the total volume of pH treated sample plated.

9.5 Sample size and power calculations

It was decided to ascertain the number of swimmers and persons not going into the water required in the study, as an estimate of the number of subjects required. Fleiss (1973) suggested that the following equation be used to obtain the required sample size from each ofthe two populations being compared:

$$n=(C_{a/2}*SQRT(2*P*Q)-C_{1-b}*SQRT(P_1*Q_1+P_2*P_2))^2/(P_2-P_1)^2,$$

where,

$a=0.05$ (the probability of infering a difference when there is none; 0.05 is a common choice according to Fleiss, 1973 and Kahn, 1983).

$C_{a/2}=1.96$

$b=0.1$ (the probability of missing a difference when one exists; 0.1 is often used according to Kahn, 1983).

$C_{1-b}=1.28$

$P_1=0.03$ (the proportion of ill persons not entering the water - from Seyfried et al., 1985a)

$P_2=0.07$ (the proportion of ill swimmers from Seyfried et al, 1985a).

$Q_1=1-P_1=0.97$

$Q_2=1-P_2=0.93$

$P=(P_1+P_2)/2=0.05$

$Q=1-P=0.95$

This caculation suggests that n is 27.9, which in turn indicates that 56 swimmers and 56 persons not entering the

9.6 Initial interview form

INITIAL INTERVIEW FORM

1

DATE: | | | | | TIME: | | | | | I.D. | | | | | | | | | | |

LEGEND: YES - 1 NO - 2 NOT APPLICABLE = blank

I. GIVEN, SURNAMES (1st then 2nd)	1.	2.	3.	4.	5.	6.
II. RELATIONSHIP TO CONTACT PERSON						
III. AGE (exact) & SEX (M=1, F=2)						
IV. SWAM IN PAST 4 DAYS? (Yes or No) OR WADED						
OTHER PLACE?						
HEAD UNDER?						
V. SWAM, OR WILL SWIM TODAY?						
HEAD UNDER?						
VI. ITALIAN						
VII CONTACT PERSON ONLY: Mother						
No. persons in household?						
No. rooms in household?						

PHYSICAL SYMPTOMS ("1" for current; "2" for past 4 days) BLANK IF NONE

1. COLD, UPPER RESPIRATORY						
2. EAR PROBLEMS						
3. STYES OR BOILS						
4. GASTROINTESTINAL						
5. ALLERGIES						
6. SUNBURN						
7. OTHER (NOTE)						

CONTACT PERSON'S FULL NAME		
ADDRESS		
POSTAL CODE		
PHONE NO.		
BEST TIME TO CALL		

NOTES

9.7 Telephone follow up form

2

TELEPHONE FOLLOWUP FORM

DATE: | | | | | I.D. | | | | | | | | | |

LEGEND: 1 - YES 2 - NO NOT APPLICABLE = blank

NAME						
I. Swam on contact day?						
In water 10 or more min. on contact day						
Head under?						
Just waded (feet in) on contact day						
Waded 10 or more min.?						
II. Swam in next 3 days?						
Which days? 1=Sun. 2=M 3=T 4=W 5=Sat.						
At this beach only? (Yes or No)						
Head under? (Yes or No) 1 2						

III. Swallow any water whilst swimming						
Did not eat food or drink at beach						
Eat food bought at beach (or drink)?						
Eat food, at beach, brought from home (or drink						

PHYSICAL SYMPTOMS - record only for 3 days after!
(Write in when first noticed) i.e. 1 = 1 day after, 2 = 2, 3 = 3
4 = contact day.
BLANK IF NONE.

A. Sore throat						
B. Fever						
C. Cold or cough						
D. Runny or stuffed nose						
E. Earache, Runny Ears						
F. Styes or red, itchy or watery eyes						
G. Stomach ache or nausea						
H. Diarrhea*						
I. Vomiting						
J. Boils						
K. Skin rash						
L. Allergenic itch, welts or sneezing						
M. Sunburn:						
N. Other symptoms						
O. Persons in res. with similar symptoms (not at beach						
P. Did you see doctor?						
Q. Diagnosis? Give in 2nd box.						
R. Did you stay at home because of illness?						
S. How many days?						

T. If illness serious, may we have your doctor's name and phone number?

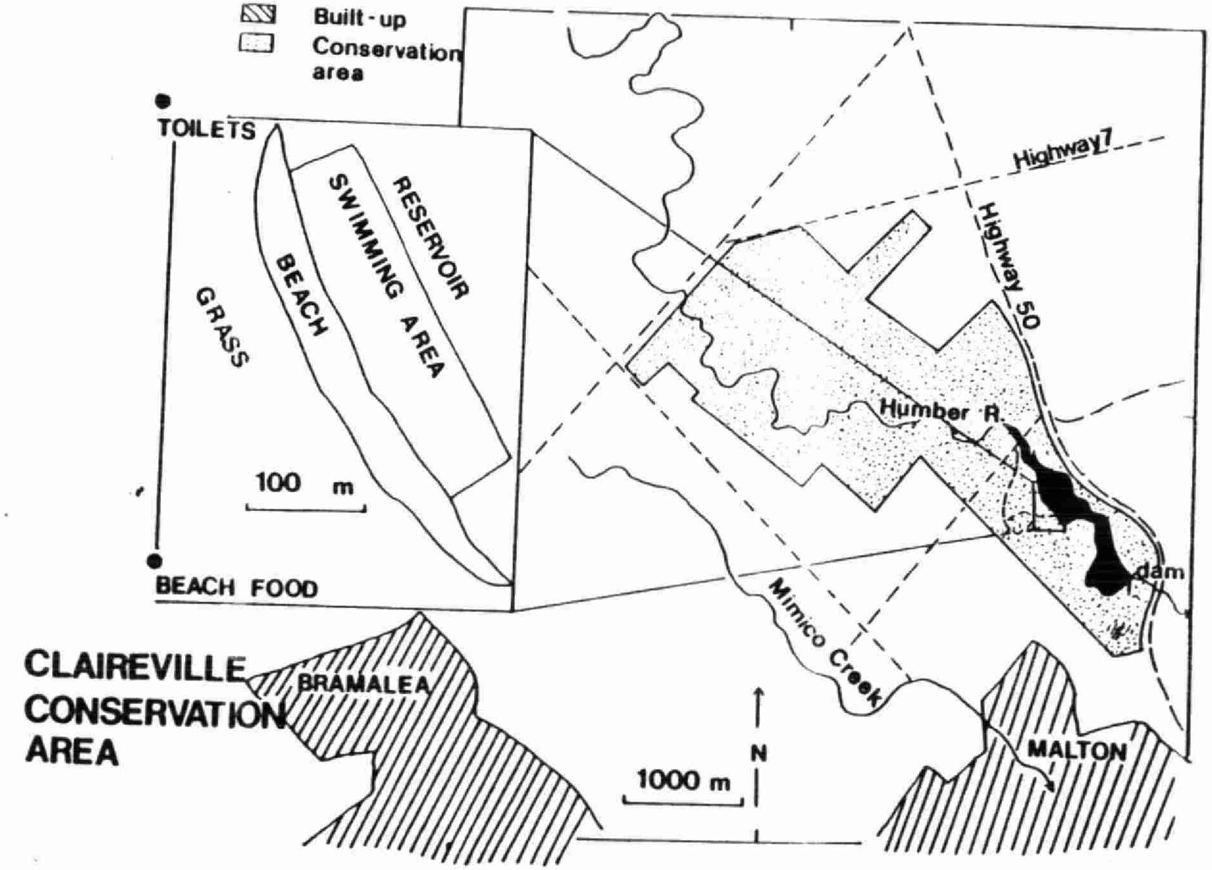

Figure 9.1 A Map of Claireville Conservation Area

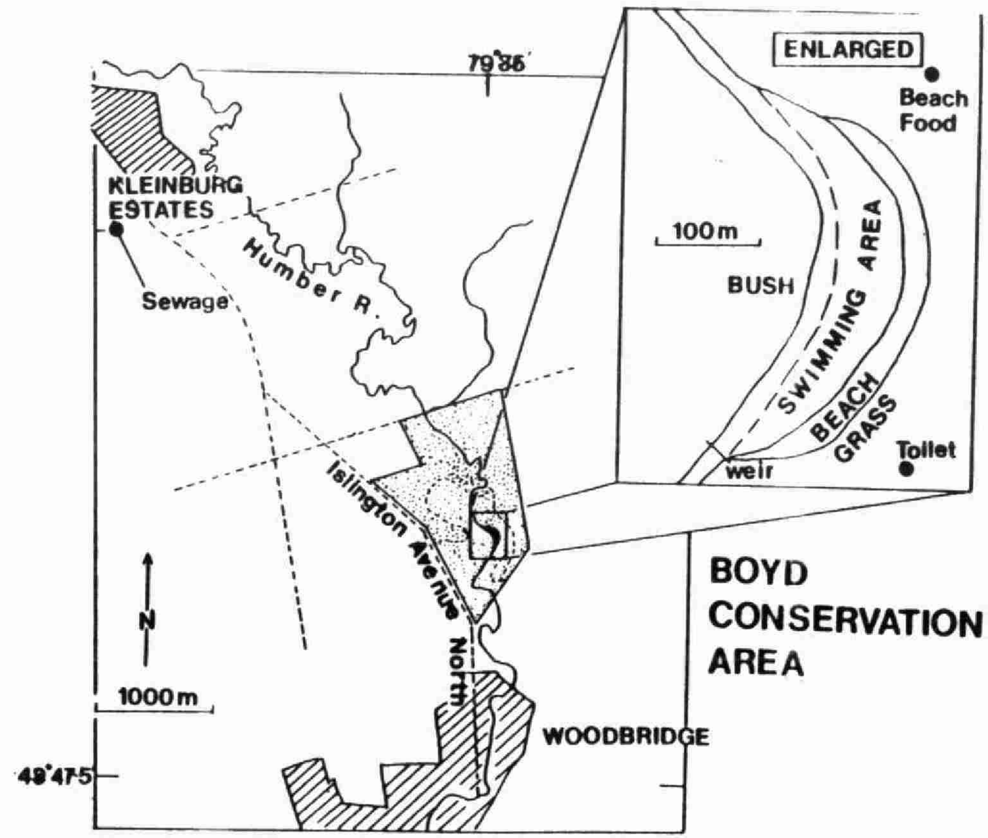

Figure 9.2 A Map of Boyd Conservation Area

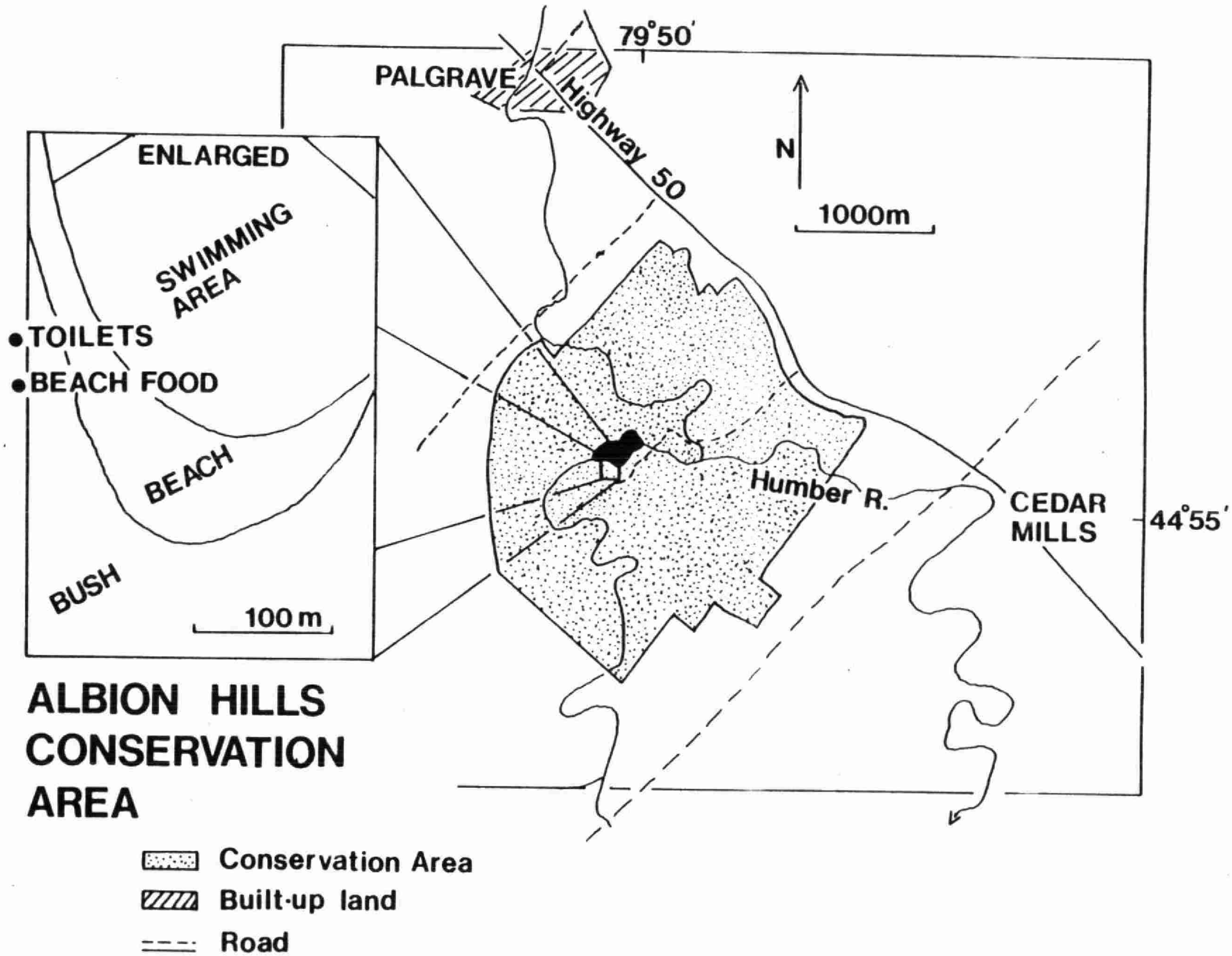

Figure 9.3 A Map of Albion Hills Conservation Area

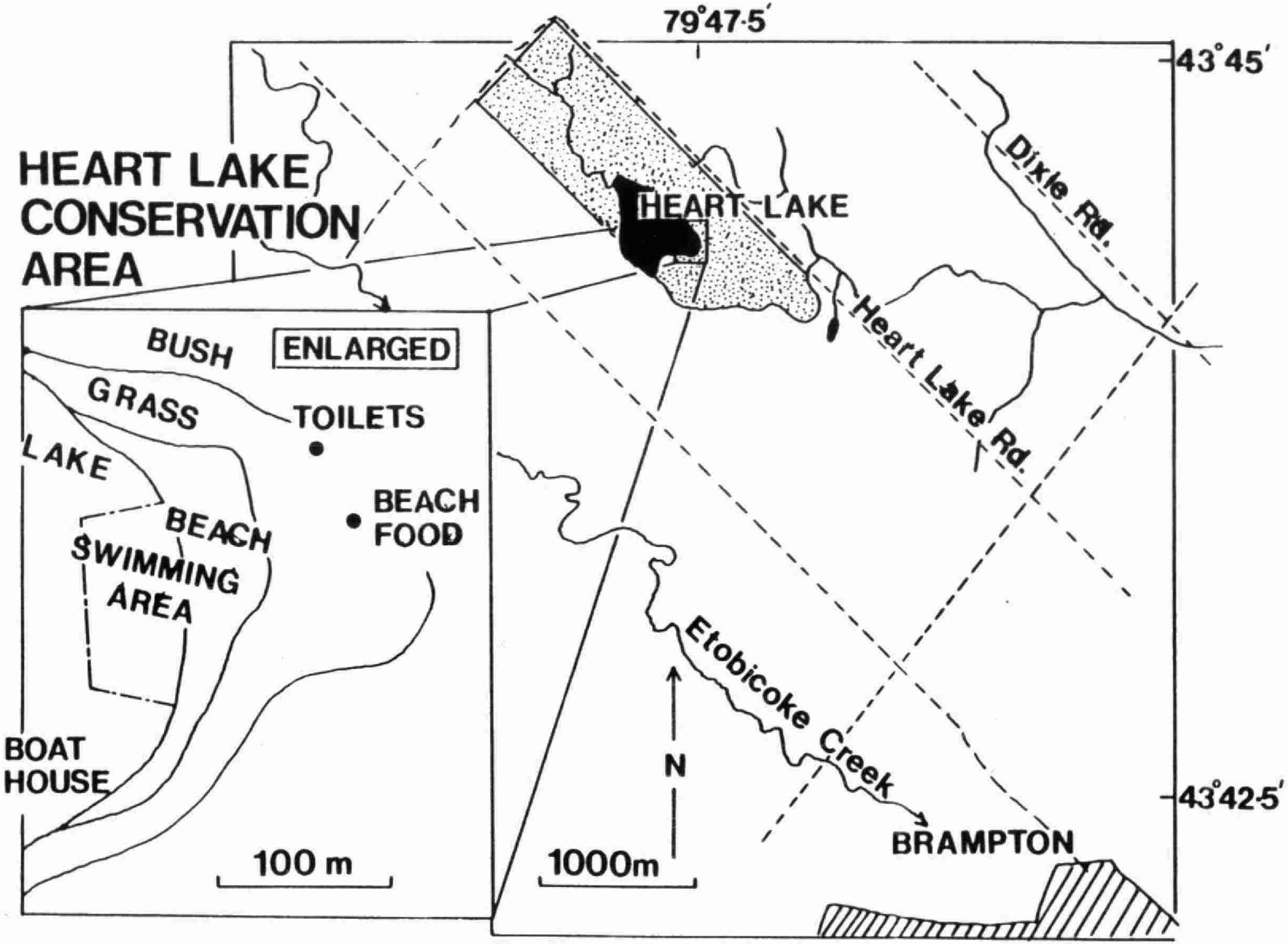

Figure 9.4 A Map of Heart Lake Conservation Area

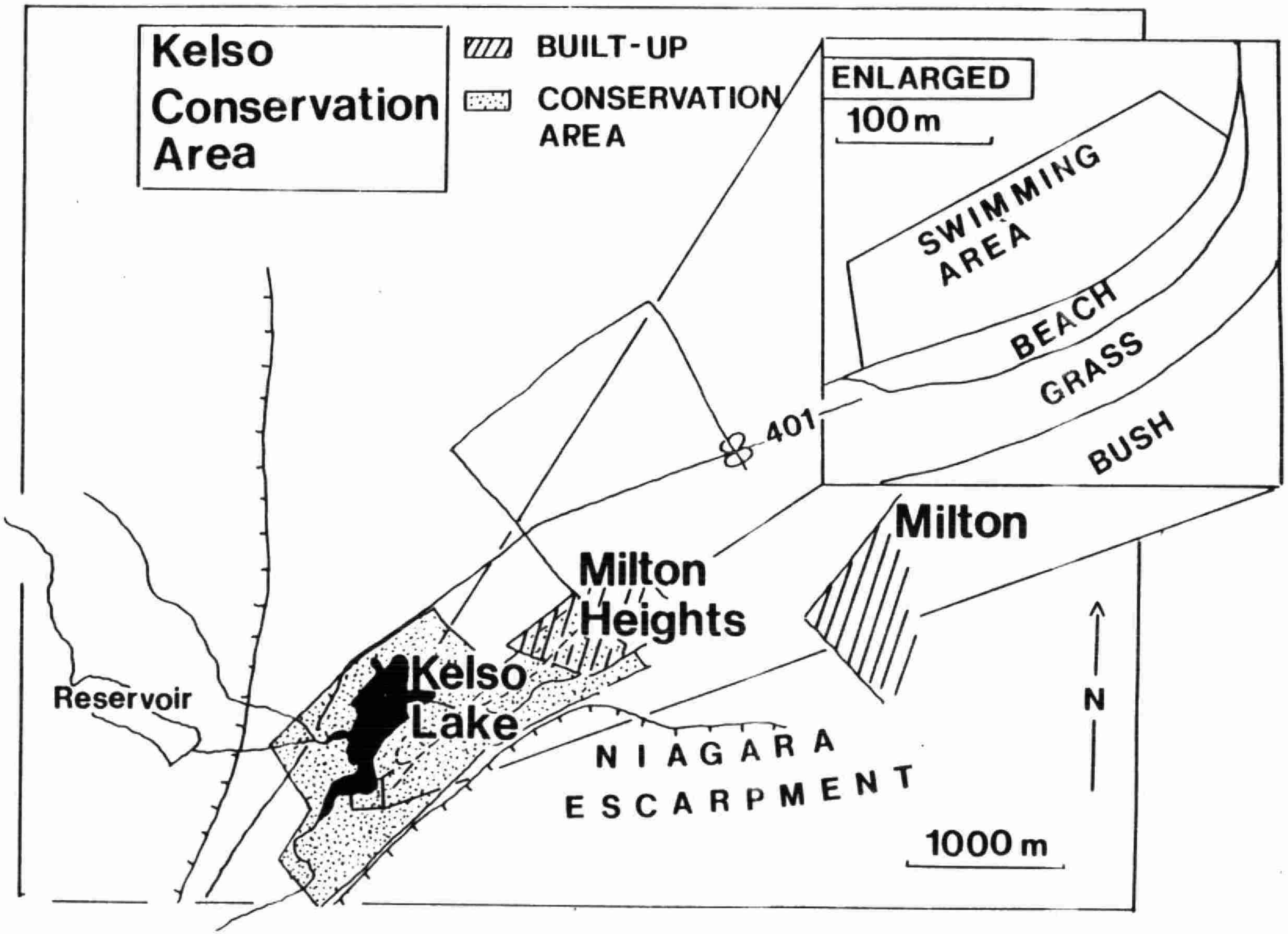

Figure 9.5 A Map of Keslo Conservation Area

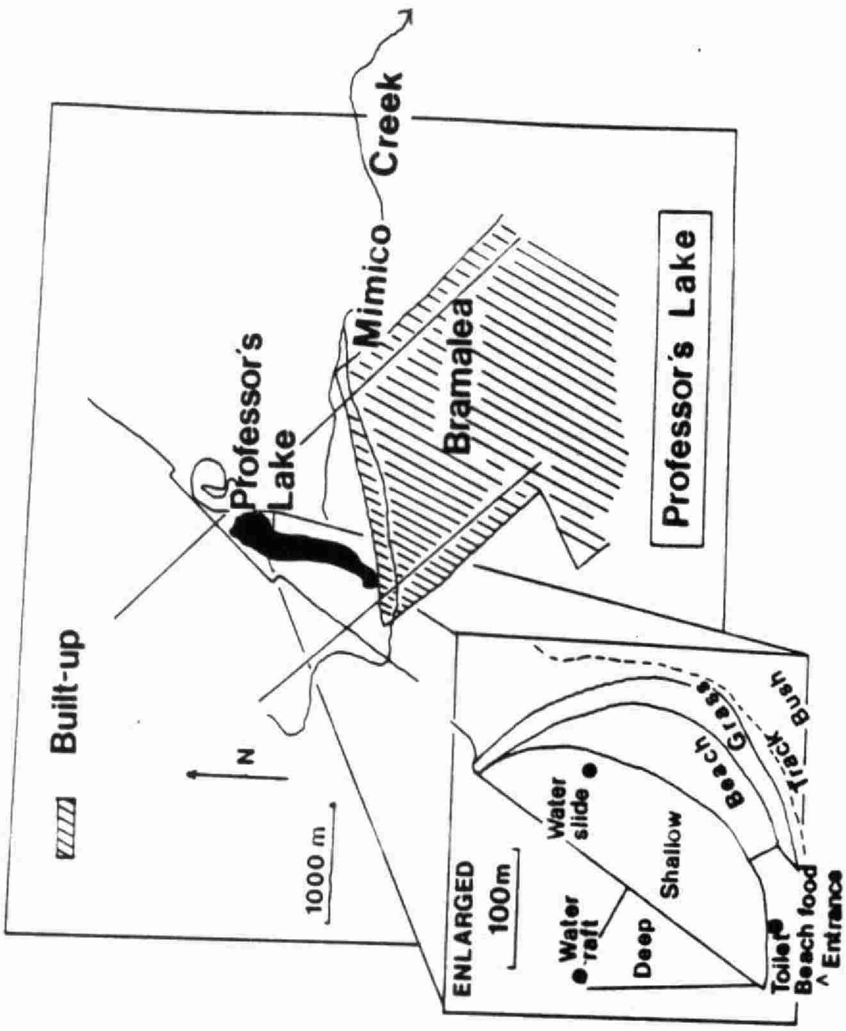

Figure 9.6 A Map of Professor's Lake

Table 9.1 Raw Bacterial Counts and Information About Beaches

BEACH=1

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
6	6	25	1	10	21.0	21.0	56	0	3
6	6	25	1	4	24.0	22.0	110	6	64
6	6	26	1	10	27.0	19.5	36	8	17
6	6	26	1	3	32.5	23.5	350	20	180
7	7	1	1	10	26.0	21.0	37	5	30
7	7	1	1	3	31.0	23.5	260	8	132
7	7	2	1	10	29.0	24.0	19	13	10
7	7	2	1	2	31.0	25.0	152	55	188
7	7	3	1	10	27.0	22.0	177	10	67
7	7	3	1	2	32.0	25.5	900	80	700
7	7	9	2	2	26.0	25.0	-	-	-
7	7	10	2	2	27.0	23.0	-	-	-
7	7	16	2	3	33.0	30.0	-	-	-
7	7	17	2	3	30.0	27.0	-	-	-
7	7	23	2	4	26.0	22.0	-	-	-
7	7	24	2	4	26.5	24.5	-	-	-
7	7	30	2	2	33.0	28.0	-	-	-
7	7	31	2	2	24.0	23.0	-	-	-
8	8	1	2	2	28.0	25.0	-	-	-
8	8	6	2	3	33.0	28.5	-	-	-
8	8	7	2	3	32.0	37.0	-	-	-
8	8	13	2	2	28.0	24.0	-	-	-
8	8	14	2	2	28.0	24.0	-	-	-
8	8	20	2	2	29.0	27.0	-	-	-
8	8	21	2	3	27.0	26.0	-	-	-
8	8	27	2	2	30.0	25.0	-	-	-
8	8	28	2	2	31.0	26.0	-	-	-

BEACH=2

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
6	6	25	1	11	19.0	24.0	18	6	21
6	6	25	1	3	24.0	24.0	50	100	10
6	6	26	1	11	29.0	23.0	33	23	100
6	6	26	1	2	35.0	25.5	70	15	250
7	7	1	1	11	28.0	25.0	20	2	45
7	7	1	1	2	31.0	26.0	190	22	160
7	7	2	1	11	30.0	26.0	37	11	21
7	7	2	1	2	31.0	26.0	210	250	112
7	7	3	1	11	20.0	26.0	178	25	170
7	7	3	1	2	32.0	28.0	300	100	350
7	7	9	1	10	20.0	22.5	13	0	3

Table 9.1 Continued

BEACH=2

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
7	7	9	1	2	27.0	24.0	120	20	50
7	7	10	1	10	22.0	22.0	84	8	17
7	7	10	1	2	32.0	24.0	700	30	210
7	7	16	1	16	31.0	26.5	24	25	50
7	7	16	1	3	35.0	28.5	300	150	300
7	7	17	1	10	28.0	26.0	100	37	120
7	7	17	1	3	32.0	27.0	450	85	450
7	7	23	2	3	25.0	23.0	-	-	-
7	7	24	2	3	25.0	24.0	-	-	-
7	7	30	2	1	32.0	29.0	-	-	-
7	7	31	2	1	23.0	25.5	-	-	-
8	8	1	2	2	31.0	26.0	-	-	-
8	8	6	2	3	34.0	28.5	-	-	-
8	8	7	2	2	31.0	28.0	-	-	-
8	8	13	2	1	28.0	24.0	-	-	-
8	8	14	2	1	26.5	24.0	-	-	-
8	8	20	2	1	29.0	26.5	-	-	-
8	8	21	2	2	28.0,	26.0	-	-	-
8	8	27	2	2	33.0	26.0	-	-	-
8	8	28	2	2	28.5	30.0	-	-	2

BEACH=3

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
6	6	25	1	12	21.0	25.0	59	8	17
6	6	25	1	2	24.0	26.0	84	61	9
6	6	26	1	12	30.0	25.0	85	12	100
6	6	26	1	1	30.0	25.0	130	7	125
7	7	1	1	10	28.0	24.0	70	45	15
7	7	1	1	1	32.0	24.5	157	10	146
7	7	2	1	11	27.5	25.5	54	12	24
7	7	2	1	1	35.0	28.0	204	17	117
7	7	3	1	11	31.5	27.0	86	5	82
7	7	3	1	1	36.0	28.0	240	10	200
7	7	9	1	11	23.5	21.0	36	1	14
7	7	9	1	2	24.0	23.0	86	4	25
7	7	10	1	11	23.0	22.0	127	6	31
7	7	10	1	2	25.0	23.0	240	7	113
7	7	16	1	11	34.0	28.0	97	12	64
7	7	16	1	2	34.5	29.0	150	10	120
7	7	17	1	11	32.0	27.0	180	25	200
7	7	17	1	2	32.0	28.0	320	28	320

Table 9.1 Continued

BEACH=3

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
7	7	23	1	11	26.0	23.0	57	1	26
7	7	23	1	2	25.5	23.5	82	0	29
7	7	24	1	11	23.5	23.0	56	3	7
7	7	24	1	2	24.0	23.0	212	5	41
7	7	30	1	11	26.0	24.5	30	3	10
7	7	30	1	2	29.5	25.5	126	11	80
7	7	31	1	11	25.0	25.0	29	2	17
7	7	31	1	12	25.5	25.0	100	12	35
8	8	1	1	11	27.0	23.5	67	0	14
8	8	1	1	2	27.0	24.5	121	2	49
8	8	6	1	12	30.0	25.0	83	3	26
8	8	6	1	3	30.0	25.5	149	7	80
8	8	7	1	11	30.0	25.0	211	11	112
8	8	7	1	2	33.5	25.0	325	10	213
8	8	13	1	11	26.0	22.0	20	1	5
8	8	13	1	2	26.5	20.5	76	5	20
8	8	14	1	11	25.0	20.0	23	0	1
8	8	14	1	2	25.0	21.5	166	1	28
8	8	20	1	11	26.0	23.5	20	0	4
8	8	20	1	2	24.0	30.0	76	6	40
8	8	21	1	11	23.5	23.5	62	0	10
8	8	21	1	2	27.5	24.5	212	16	63
8	8	27	1	12	33.0	24.5	75	8	43
8	8	27	1	2	33.5	25.0	105	6	44
8	8	28	1	12	29.0	25.0	78	1	35
8	8	28	1	2	30.0	26.0	146	9	67

BEACH=4

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
6	6	25	1	1	22.0	25.0	100	35	5
6	6	25	1	1	24.0	25.0	200	20	26
6	6	26	1	11	28.0	25.0	112	6	58
6	6	26	1	2	33.0	26.0	260	10	180
7	7	1	1	11	27.0	24.0	60	2	55
7	7	1	1	2	31.0	26.0	120	15	82
7	7	2	1	11	29.0	26.0	116	26	22
7	7	2	1	1	30.0	26.0	185	15	78
7	7	3	1	11	30.0	26.0	180	17	97
7	7	3	1	1	32.0	27.0	210	50	320
7	7	9	1	11	24.0	23.0	21	9	11
7	7	9	1	1	26.0	23.5	92	6	15

Table 9.1 Continued

BEACH=4

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
7	7	10	1	11	23.0	23.5	127	13	31
7	7	10	1	1	29.0	24.0	247	16	70
7	7	16	1	11	31.0	26.5	110	25	56
7	7	16	1	2	34.0	28.0	250	52	150
7	7	17	1	11	28.0	26.0	230	35	105
7	7	17	1	2	33.0	28.0	320	60	150
7	7	23	1	11	24.0	25.5	57	7	3
7	7	23	1	2	24.0	25.5	115	10	35
7	7	24	1	11	24.0	24.5	44	3	3
7	7	24	1	2	25.0	25.0	260	50	35
7	7	30	1	10	28.5	24.5	0	0	0
7	7	30	1	12	31.0	20.0	14	0	0
7	7	31	2	1	23.0	25.5	10	0	0
8	8	1	2	1	30.0	25.0	85	7	15
8	8	6	2	12	30.0	28.0	-	-	-
8	8	7	2	12	31.0	30.0	-	-	-
8	8	13	2	12	25.0	23.5	-	-	-
8	8	14	2	1	26.0	24.0	-	-	-
8	8	20	2	12	29.0	25.0	33	1	7
8	8	21	2	1	26.0	26.0	-	-	-
8	8	27	2	1	33.0	31.0	-	-	-
8	8	28	2	1	30.5	29.5	-	-	-

BEACH=5

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
7	7	30	1	11	28.5	25.5	35	10	19
7	7	30	1	12	29.0	25.5	166	20	53
7	7	31	1	10	26.0	25.0	50	1	10
7	7	31	1	12	25.0	25.5	90	8	40
8	8	1	1	11	23.0	25.0	100	8	40
8	8	1	1	12	29.0	25.5	130	9	42
8	8	6	2	1	31.0	27.0	-	-	-
8	8	7	2	1	32.0	28.5	-	-	30

Table 9.1 Continued

BEACH=6

MONTH	MONTH	DATE	STATUS	TIME	AIRT	WATERT	ONBEACH	HEADIN	HEADOUT
8	8	6	1	10	28.0	25.5	29	10	8
8	8	6	1	2	32.0	27.0	700	100	250
8	8	7	1	11	28.0	26.0	150	13	71
8	8	7	1	12	30.0	27.0	400	31	170
8	8	13	1	11	25.0	23.0	162	9	21
8	8	13	1	1	31.0	24.0	235	6	65
8	8	14	1	11	26.5	23.0	126	7	27
8	8	14	1	12	29.0	24.0	215	15	60
8	8	20	1	11	27.0	28.0	39	8	20
8	8	20	1	1	28.0	24.5	145	10	51
8	8	21	1	11	27.0	24.0	137	10	30
8	8	21	1	1	28.5	25.0	535	57	138
8	8	27	1	11	29.5	25.0	125	15	56
8	8	27	1	1	33.0	26.5	175	20	109
8	8	28	1	11	27.5	25.0	53	10	51
8	8	28	1	1	32.5	24.0	130	11	105

Table 9.1 Continued

BEACH=1

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
6	6	25	1	73	-	484	508	24	36	2	2
6	6	25	1	237	-	680	704	0	196	2	6
6	6	26	1	205	60	504	568	0	124	0	2
6	6	26	1	390	1020	1600	2400	0	324	80	45
7	7	1	1	480	138	1350	1480	90	463	6	3
7	7	1	1	800	388	3190	3500	217	479	23	10
7	7	2	1	73	66	430	480	38	156	30	6
7	7	2	1	140	1360	1530	1740	360	341	24	12
7	7	3	1	25	945	1590	1790	175	772	16	11
7	7	3	1	99	1970	2200	3000	372	873	109	30
7	7	9	2	32	79	232	288	20	120	192	131
7	7	10	2	23	429	260	312	41	155	128	98
7	7	16	2	118	53	2090	2200	51	131	118	140
7	7	17	2	183	725	600	660	55	270	643	398
7	7	23	2	72	4	108	108	13	42	1	0
7	7	24	2	75	8	540	640	33	91	585	11
7	7	30	2	9	28	324	404	20	70	1	0
7	7	31	2	55	501	2750	2890	-	-	39	18
8	8	1	2	10	59	380	390	61	167	9	2
8	8	6	2	22	59	152	152	13	51	6	8
8	8	7	2	36	112	112	160	46	91	341	218
8	8	13	2	9	9	204	220	37	69	2	0
8	8	14	2	23	60	164	164	31	33	0	0
8	8	20	2	13	0	68	68	29	13	8	2
8	8	21	2	27	30	180	196	11	23	4	1
8	8	27	2	12	11	236	240	19	37	16	11
8	8	28	2	31	39	372	372	32	100	13	11

BEACH=2

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
6	6	25	1	100	-	112	128	16	492	6	6
6	6	25	1	97	-	2500	2500	0	576	15	18
6	6	26	1	16	340	208	220	100	240	7	5
6	6	26	1	63	1015	908	996	100	204	15	17
7	7	1	1	50	539	120	140	38	57	0	2
7	7	1	1	50	372	1476	1604	64	117	2	3
7	7	2	1	40	-	150	1120	34	191	3	3
7	7	2	1	22	496	764	844	88	242	9	5
7	7	3	1	32	379	232	256	32	80	8	2
7	7	3	1	64	620	1370	1590	229	441	166	91
7	7	9	1	44	235	980	1530	33	95	24	8

Table 9.1 Continued

BEACH=2

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
7	7	9	1	17	555	1070	1100	17	282	4	2
7	7	10	1	119	350	100	100	13	74	23	0
7	7	10	1	62	300	910	920	103	292	389	190
7	7	16	1	59	665	1110	1210	37	118	4	8
7	7	16	1	90	635	1660	1660	119	253	218	-
7	7	17	1	10	343	730	840	157	237	1	10
7	7	17	1	57	2008	4760	4820	212	417	141	99
7	7	23	2	40	34	1108	1128	53	54	0	5
7	7	24	2	45	26	1092	1132	15	30	0	7
7	7	30	2	3	135	2020	2280	71	171	0	0
7	7	31	2	8	630	3100	4370	-	-	14	3
8	8	1	2	12	141	2500	2990	277	388	12	9
8	8	6	2	6	72	408	452	51	46	4	4
8	8	7	2	9	65	352	444	75	114	6	2
8	8	13	2	6	71	324	380	69	143	7	9
8	8	14	2	3	240	970	970	287	312	4	6
8	8	20	2	16	6470	472	804	207	256	15	5
8	8	21	2	18	400	2600	5000	387	757	7	4
8	8	27	2	9	29	1740	1940	231	357	1	2
8	8	28	2	7	202	2060	2100	149	184	2	4

BEACH=3

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
6	6	25	1	76	-	44	44	0	56	3	0
6	6	25	1	114	-	108	132	0	68	0	8
6	6	26	1	72	130	108	108	0	8	0	0
6	6	26	1	140	50	108	112	0	48	0	6
7	7	1	1	80	62	188	200	20	63	0	0
7	7	1	1	40	65	120	130	16	85	9	3
7	7	2	1	53	44	256	268	8	63	4	0
7	7	2	1	121	112	284	296	18	74	8	5
7	7	3	1	31	167	812	838	17	88	1	1
7	7	3	1	8	209	1200	1300	65	169	14	27
7	7	9	1	57	11	128	132	11	13	2	0
7	7	9	1	52	332	180	188	6	53	0	0
7	7	10	1	105	79	28	28	0	15	2	0
7	7	10	1	96	170	228	248	37	67	4	9
7	7	16	1	36	49	80	80	37	15	4	2
7	7	16	1	89	55	472	472	11	36	4	6
7	7	17	1	9	118	128	128	16	37	0	16
7	7	17	1	83	513	220	300	25	277	0	17

Table 9.1 Continued

BEACH=3

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
7	7	23	1	9	30	288	312	9	12	0	2
7	7	23	1	550	109	612	612	61	372	1	5
7	7	24	1	120	7	128	156	5	56	0	1
7	7	24	1	22	319	500	570	30	34	11	4
7	7	30	1	11	53	472	744	44	81	0	1
7	7	30	1	9	92	836	876	61	145	7	6
7	7	31	1	14	106	970	1160	172	288	5	3
7	7	31	1	27	357	1330	1490	211	396	224	169
8	8	1	1	10	102	1250	1340	97	388	56	24
8	8	1	1	37	171	1380	1620	101	304	14	23
8	8	6	1	24	157	780	850	115	119	3	3
8	8	6	1	36	234	850	1160	69	73	3	13
8	8	7	1	30	877	572	636	51	720	19	16
8	8	7	1	39	199	868	956	115	97	30	38
8	8	13	1	22	25	56	84	8	10	6	2
8	8	13	1	7	65	576	596	19	25	7	5
8	8	14	1	8	116	84	84	13	51	14	5
8	8	14	1	22	420	280	280	19	40	12	3
8	8	20	1	6	65	624	648	41	15	6	5
8	8	20	1	14	33	392	428	24	15	4	3
8	8	21	1	15	4	196	224	5	13	4	0
8	8	21	1	51	160	544	660	29	61	3	1
8	8	27	1	15	54	436	440	33	47	1	3
8	8	27	1	18	87	440	448	23	24	3	4
8	8	28	1	14	62	108	112	7	4	2	4
8	8	28	1	31	328	372	400	29	61	20	25

BEACH=4

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
6	6	25	1	15	-	100	162	34	100	1	1
6	6	25	1	16	-	322	338	0	84	15	44
6	6	26	1	41	448	106	142	0	188	28	6
6	6	26	1	28	838	348	384	100	320	36	20
7	7	1	1	250	133	72	72	16	46	0	0
7	7	1	1	92	78	380	450	28	88	16	13
7	7	2	1	4	112	10	26	14	93	97	23
7	7	2	1	7	548	76	102	44	122	28	7
7	7	3	1	54	561	3710	3710	161	-	59	18
7	7	3	1	51	458	684	776	45	7	42	26
7	7	9	1	8	90	168	168	11	80	0	0
7	7	9	1	8	140	102	116	45	44	0	1

Table 9.1 Continued

BEACH=4

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
7	7	10	1	30	383	108	116	15	215	0	1
7	7	10	1	32	636	-	-	-	-	23	26
7	7	16	1	43	343	530	580	31	25	7	2
7	7	16	1	30	457	316	356	49	133	14	23
7	7	17	1	6	263	68	72	32	77	22	14
7	7	17	1	16	1305	230	290	41	286	175	113
7	7	23	1	31	118	440	610	69	307	9	10
7	7	23	1	13	67	480	700	61	198	2	9
7	7	24	1	33	24	264	292	13	41	0	0
7	7	24	1	63	65	396	476	29	35	3	4
7	7	30	1	4	157	96	96	7	80	0	0
7	7	30	1	31	133	364	416	127	100	0	10
7	7	31	2	107	347	9200	9400	116	527	18	15
8	8	1	2	129	877	-	-	517	-	25	16
8	8	6	2	-	1053	110	150	39	27	2	0
8	8	7	2	-	1560	470	510	39	59	6	1
8	8	13	2	29	18	332	484	19	37	0	0
8	8	14	2	90	149	464	496	152	112	2	1
8	8	20	2	45	19	60	76	369	310	6	0
8	8	21	2	22	73	52	52	43	41	2	0
8	8	27	2	37	12	10	10	113	113	0	28
8	8	28	2	42	12	8	16	119	223	0	14

BEACH=5

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
7	7	30	1	6	24	1060	1090	30	158	13	2
7	7	30	1	2	300	930	1000	63	145	20	5
7	7	31	1	94	295	6400	7900	568	-	321	331
7	7	31	1	25	483	3590	4120	450	717	63	35
8	8	1	1	7	51	630	730	71	67	101	75
8	8	1	1	9	326	1260	1310	72	132	94	47
8	8	6	2	51	51	344	348	17	15	7	17
8	8	7	2	35	1273	484	620	28	19	2	1

Table 9.1 Continued

BEACH=6

MONTH	MONTH	DATE	STATUS	HET	STAPH	ECOLI	FECAL	ENTERO	STREP	PAMPA	PATIN
8	8	6	1	2	11	52	54	0	20	0	0
8	8	6	1	8	274	1712	1824	137	131	84	50
8	8	7	1	3	39	400	700	41	31	7	6
8	8	7	1	11	42	1012	1352	43	78	12	7
8	8	13	1	8	11	48	104	23	13	6	3
8	8	13	1	9	66	56	88	15	16	31	6
8	8	14	1	4	34	280	320	51	31	1	1
8	8	14	1	1	162	168	196	55	66	2	2
8	8	20	1	2	7	48	48	5	9	1	0
8	8	20	1	9	21	1264	1296	270	221	7	2
8	8	21	1	9	65	304	388	39	87	4	1
8	8	21	1	12	151	308	392	44	48	3	3
8	8	27	1	1	47	20	52	3	12	0	3
8	8	27	1	3	89	228	336	15	21	7	3
8	8	28	1	2	5	12	12	4	2	1	0
8	8	28	1	4	129	184	204	39	23	3	3

Table 9.1 Continued

Legend:

Beach 1 - Botd C.A. (Conservation Area)
2 - Claireville C.A.
3 - Albion Hills C.A.
4 - Heart Lake C.A.
5 - Kelso C.A.
6 - Professor's Lake

Status: 1 - open, 2 - closed

Time: time of day to nearest hour

Airt: air temperature

Watert: water temperature

Onbeach: estimate of the number of persons on the beach

Headout: estimate of the number of persons with head not underwater

Het: heterotrophic count
Staph: total staphylococcal count
Ecoli: E. coli count
Fecal: fecal coliform count
Entero: enterococcal count
Strep: fecal streptococcal count
Pampa: P. aeruginosa (on mPA) count
Patin: P. aeruginosa (on mTIN) count

Table 9.2 Raw data from Professor's Lake Pilot Study of Bacteriological Sampling Proceedures and Data Quality Evaluation

	AUGUST 13							
SAMPLE	Total staphylococci	Heterotrophs	Fecal coliforms	*E. coli*	Enterococci	Fecal streptococci	*P. aeruginosa*	*P. aeruginosa*
N-1	73	1076667	96	40	8	7	3	0
N-2	95	1663333	132	128	15	23	25	2
N-3	56	1320000	79	80	15	12	28	2
N-4	298	1726667	1543	1290	179	184	34	3
N-5	172	2460000	184	152	11	23	36	5
N-6	154	4700000	356	268	46	48	21	4
O-7	0	1380000	8	4	3	2	1	0
O-8	5	1273333	0	0	0	2	0	0
O-9	128	180000	31	20	6	7	7	0
O-10	41	103333	193	156	44	60	2	1
O-11	0	30000	12	8	0	2	0	0
O-12	0	1705000	7	4	3	0	0	0

Legend: N-nearshore, O-offshore

Table 9.2 Continued

SAMPLE	AUGUST 14							
	Total staphylococci	Heterotrophs	Fecal coliforms	*E. coli*	Enterococci	Fecal streptococci	*P. aeruginosa*	*P. aeruginosa*
N-1	84	693333	41	44	9	32	6	3
N-2	151	320000	262	208	127	121	38	5
N-3	206	570000	317	288	57	49	11	8
N-4	75	25360000	408	408	69	66	10	9
N-5	241	9696667	482	516	67	94	11	7
N-6	253	6086667	833	928	153	124	9	10
N-7	8	1276667	49	24	4	9	6	1
O-8	55	58400000	75	56	15	23	6	0
O-9	76	swarm	97	60	9	2	9	1
O-10	108	150000	225	220	35	39	10	6
O-11	153	30000	0	0	5	0	2	0
O-12	0	8000000	4	4	0	0	0	0

Table 9.2 Continued

SAMPLE	AUGUST 20							
	Total staphylococci	Heterotrophs	Fecal coliforms	*E. coli*	Enterococci	Fecal streptococci	*P. aeruginosa*	*P. aeruginosa*
N-1	117	820000	355	332	53	54	11	14
N-2	28	650000	11	4	0	2	0	0
N-3	14	1076667	4	4	0	0	0	0
N-4	24	40000	133	152	15	20	0	0
N-5	4	165000	83	76	14	15	0	0
N-6	17	653333	512	444	42	66	5	1
O-7	30	576667	64	92	11	4	1	2
O-8	58	996667	11	10	2	0	1	0
O-9	0	346667	12	12	0	2	0	0
O-10	7	350000	4	4	4	0	0	0
O-11	0	60000	4	4	0	2	0	0
O-12	66	20000	9	8	0	2	0	0

Table 9.3 Humber River Bacterial and Trace Element Data

Sample number		1	2	3	4	5	6	7	8	9
Staph.	1	31	31	71	45	1115	7	12	31	12
Staph.	2	275	165	42	22	59	28	25	24	12
Het.	1	4.0	6.4	5.9	6.6	4.8	2.5	1.7	0.3	3.2
Het.	2	3.6	7.6	2.1	1.8	1.7	1.5	2.4	1.5	2.5
FC.	1	313	753	1178	1213	24300	230	124	139	120
FC.	2	4750	3280	696	478	470	495	494	79	528
EC.	1	340	870	800	1100	24100	280	496	136	140
EC.	2	6040	3280	876	724	700	600	632	72	692
Ent.	1	100	87	105	66	2020	13	25	257	25
Ent.	2	207	205	95	42	52	29	24	49	49
FS.	1	285	144	174	165	1672	67	95	174	113
FS	2	620	668	242	99	144	80	144	103	149
MPA	1	6	6	5	3	2	0	0	0	0
MPA	2	11	18	1	1	0	2	2	1	0
MTIN	1	6	6	1	1	3	0	0	0	0
MTIN	2	19	37	0	0	3	2	2	0	1
P	1	0.3	0.1	0.1	0.0	0.1	0.3	0.3	0.1	0.3
P	2	0.4	0.3	0.3	0.6	0.6	0.5	0.3	0.2	0.2
Mo	1	n.d.	n.d.	n.d.	n.d.	n.d.	0.01	0.02	n.d.	0.02
Mo	2	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01
Ca	1	63	73	94	97	95	83	83	127	82
Ca	2	62	66	77	77	89	81	68	71	71
Al	1	0.08	0.08	0.02	n.d.	n.d.	0.01	n.d.	0.01	n.d.
Al	2	0.09	0.09	0.10	0.09	0.06	0.06	0.11	0.10	0.10
Zn	1	0.02	0.01	n.d.	n.d.	n.d.	0.02	0.02	0.03	0.07
Zn	2	0.01	0.01	0.01	0.02	0.01	0.01	n.d.	0.02	0.01
Fe	1	0.05	0.09	0.05	0.05	0.04	0.03	0.04	0.01	0.05
Fe	2	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Mg	1	22	24	27	28	28	23	23	32	23
Mg	2	20	21	22	21	23	22	21	32	21
S	1	12	13	17	17	18	14	14	25	14
S	2	11	12	14	13	14	14	12	24	13
Grid Ref.		131478	135489	142502	140510	138512	138153	138158	138158	134525
Time	1	9.49	10.05	10.16	10.29	10.38	10.50	10.56	11.03	11.21
Time	2	9.45	9.50	10.02	10.17	10.24	10.10	10.45	10.55	11.05

Table 9.3 Continued

Sample number		10	11	12	13	14	15	16	17	18
Staph.	1	17	10	15	45	17	33	266	40	18
Staph.	2	81	73	104	271	1310	19	39	34	39
Het.	1	4.6	1.3	1.5	1.2	2.4	1.6	2.7	3.0	18.5
Het.	2	1.7	0.9	1.0	1.7	4.3	2.2	2.9	1.7	2.3
FC.	1	582	259	627	1573	547	75	234	1120	1671
FC.	2	608	960	647	699	5470	1140	162	1574	724
EC.	1	1076	428	732	248	71200	72	416	1150	1840
EC.	2	772	1004	960	840	832	2430	200	1144	1120
Ent.	1	63	63	125	38	43	26	61	165	25
Ent.	2	105	122	109	42	317	44	19	212	25
FS.	1	293	189	244	109	1482	149	185	397	139
FS	2	373	403	199	103	942	225	764	516	150
MPA	1	1	0	1	0	4	0	29	0	0
MPA	2	3	1	0	0	2	1	22	1	0
MTIN	1	0	1	0	0	2	1	22	1	0
MTIN	2	4	1	5	3	36	8	2	4	1
P	1	0.4	0.1	0.4	0.3	0.2	0.7	0.3	0.4	0.4
P	2	0.3	0.3	0.3	0.3	0.4	0.5	0.4	0.3	0.5
Mo	1	0.02	0.02	0.01	0.02	0.02	n.d.	n.d.	n.d.	n.d.
Mo	2	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Ca	1	86	70	68	69	60	60	58	597	67
Ca	2	75	64	63	66	57	62	51	54	59
Al	1	0.02	n.d.	0.04	n.d.	0.07	n.d.	0.03	n.d.	0.06
Al	2	0.07	0.11	0.10	0.07	0.14	0.08	0.05	0.07	0.09
Zn	1	0.04	0.05	0.09	0.03	0.01	0.02	0.02	0.03	0.01
Zn	2	0.01	0.01	0.01	0.02	0.07	0.06	0.03	0.05	0.03
Fe	1	0.03	0.05	0.05	0.05	0.07	0.06	0.03	0.05	0.03
Fe	2	0.01	0.02	0.01	0.02	0.05	0.03	0.01	0.01	0.02
Mg	1	22	24	24	25	20	20	29	22	23
Mg	2	22	22	22	22	17	19	22	20	23
S	1	15	11	11	11	9	10	26	18	12
S	2	12	12	11	10	11	11	21	16	15
Grid Ref.		129539	119542	105554	097577	099551	100534			
Time	1	11.41	12.03	12.28	12.37	12.55	13.08	14.47	15.15	15.39
Time	2	11.25	11.45	12.10	12.32	13.22	13.18	15.27	15.40	17.58

Table 9.3 Continued

Sample number		19	20	21	22	23	24	25	26	27
Staph.	1	266	50	63	45	45	74	61	44	44
Staph.	2	24	69	127	82	245	109	n.a.	n.a.	n.a.
Het.	1	11.3	1.6	3.4	0.4	0.8	1.1	0.9	0.9	0.7
Het.	2	1.9	1.1	0.6	0.9	1.0	1.1	n.a.	n.a.	n.a.
FC.	1	8300	1124	441	408	229	142	132	151	382
FC.	2	44	1473	1697	1210	1081	1620	n.a.	n.a.	n.a.
EC.	1	7200	1496	592	460	500	220	152	160	550
EC.	2	32	1540	1690	1530	1112	1170	n.a.	n.a.	n.a.
Ent.	1	357	38	16	25	25	21	8	277	53
Ent.	2	8	363	190	198	181	215	n.a.	n.a.	n.a.
FS.	1	408	63	39	55	39	45	33	122	121
FS	2	47	890	443	419	537	488	n.a.	n.a.	n.a.
MPA	1	1	6	0	0	6	1	3	1	1
MPA	2	0	23	6	9	7	4	n.a.	n.a.	n.a.
MTIN	1	3	1	0	0	1	1	2	2	0
MTIN	2	0	11	5	7	8	1	n.a.	n.a.	n.a.
P	1	0.3	0.2	0.4	0.4	0.2	0.1	0.2	0.3	0.3
P	2	0.2	0.4	0.4	0.8	0.5	0.5	n.a.	n.a.	n.a.
Mo	1	0.02	n.d.	n.d.	0.02	0.02	0.01	n.d.	n.d.	0.01
Mo	2	0.01	0.01	0.01	0.01	0.01	0.01	n.a.	n.a.	n.a.
Ca	1	75	82	86	82	86	83	84	837	78
Ca	2	62	67	69	69	68	71	n.a.	n.a.	n.a.
Al	1	0.02	0.05	n.d.	0.05	n.d.	0.02	0.02	n.d.	0.04
Al	2	0.07	0.08	0.07	0.08	0.09	0.10	n.a.	n.a.	n.a.
Zn	1	0/03	0.02	0.02	0.02	0.06	0.01	0.02	0.03	0.01
Zn	2	0.02	0.03	0.02	0.01	0.02	0.01	n.a.	n.a.	n.a.
Fe	1	0.05	0.03	0.02	0.03	0.03	0.02	0.03	0.03	0.04
Fe	2	0.03	0.01	0.01	0.01	0.02	0.01	n.a.	n.a.	n.a.
Mg	1	22	21	22	21	22	22	22	22	22
Mg	2	22	20	20	20	20	21	n.a.	n.a.	n.a.
S	1	17	17	17	16	17	16	17	17	15
S	2	17	15	15	15	15	15	n.a.	n.a.	n.a.
Grid Ref.		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Time	1	16.36	16.41	16.50	16.51	16.53	17.03	17.05	17.27	17.39
Time	2	17.28	17.34	17.45	17.50	17.55	18.00	n.a.	n.a.	n.a.

Table 9.3 Continued

Sample number		28	29	30	31	32	33	34	39	40
Staph.	1	9	39	29	118	10	13	116	n.a.	n.a.
Staph.	2	33	n.a.	99	685	38	n.a.	n.a.	151	350
Het.	1	1.9	2.5	2.0	4.9	1.7	2.0	3.0	n.a.	n.a.
Het.	2	1.9	n.a.	2.8	6.1	3.1	n.a.	n.a.	3.5	4.9
FC.	1	11	178.	395	296	469	80	79	n.a.	n.a.
FC.	2	977	n.a.	965	1278	704	n.a.	n.a.	2463	10270
EC.	1	4	170	390	520	644	128	60	n.a.	n.a.
EC.	2	1100	n.a.	1052	1060	756	n.a.	n.a.	2050	9440
Ent.	1	18	50	107	299	24	18	23	n.a.	n.a.
Ent.	2	47	n.a.	107	121	59	n.a.	n.a.	336.	750
FS.	1	43	105	149	598	69	64	595	n.a.	n.a.
FS	2	237	n.a.	247	414	218	n.a.	n.a.	1013	4245
MPA	1	1	2	1	2	0	0	09	n.a.	n.a.
MPA	2	4	n.a.	2	5	2	n.a.	n.a.	8	0
MTIN	1	0	1	1	0	0	0	0	n.a.	n.a.
MTIN	2	7	n.a.	6	0	0	n.a.	n.a.	7	0
P	1	0.2	0.2	0.2	0.2	0.50	0.1	0.1	n.a.	n.a.
P	2	0.2	n.a.	0.3	0.2	0.4	n.a.	n.a.	1.0	0.5
Mo	1	0.01	0.01	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.
Mo	2	0.01	n.a.	0.01	0.02	0.02	n.a.	n.a.	0.02	0.01
Ca	1	49	54	79	103	69	79	81	n.a.	n.a.
Ca	2	56	n.a.	77	64	71	n.a.	n.a.	55	59
Al	1	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.
Al	2	0.10	n.a.	0.09	0.10	0.10	n.a.	n.a.	0.20	0.10
Zn	1	0.01	0.01	0.01	n.d.	n.d.	0.01	n.d.	n.a.	n.a.
Zn	2	0.01	n.a.	0.01	n.d.	0.01	n.d.	n.d.	0.02	0.01
Fe	1	0.04	0.04	0.05	0.05	0.05	0.03	0.03	n.a.	n.a.
Fe	2	0.03	n.a.	0.02	0.02	0.02	n.a.	n.a.	0.02	0.03
Mg	1	27	20	26	23	25	23	24	n.a.	n.a.
Mg	2	18	n.a.	19	14	23	n.a.	n.a.	21	21
S	1	15	10	11	19	10	15	15	n.a.	n.a.
S	2	10	n.a.	14	15	10	n.a.	n.a.	13	24
Grid Ref.		n.a.	n.a.	114616	143623	087597	n.a.	n.a.	n.a.	n.a.
Time	1	17.05	17.27	17.39	18.51	19.03	19.20	19.24	n.a.5	n.a.
Time	2	13.46	n.a	12.45	12.55	13.07	n.a.	n.a.	n.a.	n.a.

Table 9.3 Continued

Sample number	41	42	43
Staph. 1	n.a.	n.a.	n.a.
Staph. 2	44	256	7
Het. 1	n.a.	n.a.	n.a.
Het. 2	2.7	3.3	1.9
FC. 1	n.a.	n.a.	n.a.
FC. 2	94	44	126
EC. 1	n.a.	n.a.	n.a.
EC. 2	124	3240	232
Ent. 1	n.a.	n.a.	n.a.
Ent. 2	15	151	14
FS. 1	n.a.	n.a.	n.a.
FS 2	60	355	55
MPA 1	n.a.	n.a.	n.a.
MPA 2	0	0	0
MTIN 1	n.a.	n.a.	n.a.
MTIN 2	0	1	0
P 1	n.a.	n.a.	n.a.
P 2	0.6	0.3	0.4
Mo 1	n.a.	n.a.	n.a.
Mo 2	0.01	0.01	0.01
Ca 1	n.a.	n.a.	n.a.
Ca 2	58	n.d.	55
Al 1	n.a.	n.a.	n.a.
Al 2	0.09	0.06	0.09
Zn 1	n.a.	n.a.	n.a.
Zn 2	0.03	0.01	0.01
Fe 1	n.a.	n.a.	n.a.
Fe 2	0.03	0.01	0.01
Mg 1	n.a.	n.a.	n.a.
Mg 2	19	35	23
S 1	n.a.	n.a.	n.a.
S 2	27	53	15
Grid Ref.	n.a.	n.a.	n.a.
Time 1			
Time 2	16.58	17.09	17.18

Legend:
Staph. - total staphylococci, Het - heterotrophs, FC - fecal coliforms, EC - E. coli, Ent - enterococci, FS - fecal streptococci, MPA - P. aeruginosa (on mPA), and MTIN - P. aeruginosa (on mTIN).
Elemental concentrations are given in ppm.
Grid. Ref. - grid reference, n.a. - not available.

Table 9.4 Crude epidemiological data for the overall population (n=8420), and for swimmers, waders, and persons who did not enter the water.

VARIABLE	OVERALL (n=8420)	WADESWIM WADERS 1 (n=574)	SWIMMERS 2 (n=6653)	NOT IN WATER 3 (n=1193)
ILL	558	24	511	23
NOT ILL	7862	550	6142	1170
EAR SYMPTOMS	69	3	64	2
NO EAR SYMPTOMS	8351	571	6589	1191
SKIN SYMPTOMS	60	1	56	3
NO SKIN SYMPTOMS	8351	571	6589	1191
EYE SYMPTOMS	67	3	61	3
NO EYE SYMPTOMS	8353	571	6592	1190
RESPIRATORY SYMPTOMS	232	9	216	7
NO RESPIRATORY SYMPTOMS	8188	565	6437	1186
GI SYMPTOMS	159	9	144	6
NO GI SYMPTOMS	8261	565	6509	1187

Table 9.4 Continued

VARIABLE	OVERALL (n=8420)	WADESWIM: WADERS 1 (n=574)	WADESWIM: SWIMMERS 2 (n=6653)	WADESWIM: NOT IN WATER 3 (n=1193)
ITALIAN	2457	153	1878	426
NOT ITALIAN	5963	421	4775	767
INTERVIEWER 1	83	0	68	15
2	119	20	70	29
3	574	46	417	111
4	843	63	690	90
5	213	12	165	36
6	696	26	563	107
7	1794	87	1669	38
8	703	57	534	112
9	1034	57	821	156
10	67	7	50	10
11	82	9	56	17
12	749	75	490	184
13	842	53	613	176
14	621	62	447	112
SWALLOWED WATER	1692	0	1692	0
DID NOT SWALLOW WATER	6728	574	4961	1193
HEAD UNDER WATER	5528	0	5528	0
DID NOT PUT HEAD UNDER WATER	2892	574	1125	1193
SOCIOECONOMIC GROUP 1	5602	358	4434	810
2	1663	131	1309	223
3	1155	85	910	160
FOOD 1	617	26	504	87
2	4295	312	3210	773
3	1244	81	1050	113
4	2264	155	1889	220
SEX MALE	3910	224	3182	504
FEMALE	4510	350	3471	689
NEWSBA 1	3033	133	2725	175
2	6387	441	3928	1018
NEWCP 1	1999	205	1455	339
2	6421	369	5198	854
AVERAGE AGE	22.55	26.79	20.56	31.58

Full definitions of variables are given in Chapter 5.

Table 9.5 Crude Epidemiological Data for Each Beach

VARIABLE	BEACH					
	1 (n=1041)	2 (n=1448)	3 (n=2649)	4 (n=1458)	5 (n=467)	6 (n=1357)
ILL	50	114	174	143	467	1357
NOT ILL	991	1334	2475	1315	448	1299
EAR SYMPTOMS	4	16	21	22	3	3
NO EAR SYMPTOMS	1037	1432	2628	1436	464	1354
SKIN SYMPTOMS	3	21	16	18	0	2
NO SKIN SYMPTOMS	1038	1427	2633	1440	467	1355
EYE SYMPTOMS	1	18	25	14	1	8
NO EYE SYMPTOMS	1040	1430	2624	1444	466	1349
RESPIRATORY SYMPTOMS	24	44	72	62	7	23
NO RESPIRATORY SYMPTOMS	1017	1404	2577	1396	460	1334
GI SYMPTOMS	9	33	45	40	9	23
NO GI SYMPTOMS	1032	1415	2604	1418	458	1334

Table 9.5 Continued

VARIABLE	BEACH 1 (n=1041)	2 (n=1448)	3 (n=2649)	4 (n=1458)	5 (n=467)	6 (n=1357)
ITALIAN	515	606	754	330	48	204
NOT ITALIAN	526	842	1895	1128	419	1153
INTERVIEWER 1	0	0	83	0	0	0
2	0	0	0	119	0	0
3	0	226	207	39	73	29
4	178	76	212	0	74	303
5	0	0	213	0	0	0
6	0	280	235	153	28	0
7	456	109	461	0	182	586
8	7	282	83	205	28	28
9	0	0	252	531	0	251
10	0	0	67	0	0	0
11	0	0	82	0	0	0
12	97	196	167	289	0	0
13	233	89	292	0	68	160
14	0	190	295	122	14	0
SWALLOWED WATER	173	249	499	213	97	461
DID NOT SWALLOW WATER	868	1199	2150	1245	370	896
HEAD UNDER WATER	687	878	1745	790	315	1113
DID NOT PUT HEAD UNDER WATER	354	570	904	668	152	244
SOCIOECONOMIC GROUP 1	737	984	1721	961	296	903
2	135	275	566	324	112	251
3	169	189	362	173	59	203
FOOD 1	34	129	159	100	46	251
2	646	885	1221	825	305	149
3	91	149	363	157	35	449
4	270	285	906	376	81	346
SEX MALE	467	684	1232	723	215	589
FEMALE	574	764	1417	735	252	768
NEWSBA 1	337	483	999	458	165	591
2	704	965	1650	1000	302	766
NEWCP 1	225	329	643	368	105	329
2	816	1119	2006	1090	362	1028
WADESWIM 1	61	83	158	119	52	101
2	828	1138	2152	975	355	1205
3	152	227	339	364	60	51
AVERAGE AGE	22.85	22.49	22.99	23.06		23.43

Full definitions of variables are given in Chapter 5.

Table 9.6 Crude Epidemiological Data for Swimmers, Waders, and Persons Who Did Not Enter the Water at Each Beach

VARIABLE	BEACH 1 WADEDSWIM 1 (n=61)	2 (n=828)	3 (n=152)	BEACH 2 WADESWIM 1 (n=83)	2 (n=1138)	3 (n=227)
ILL	2	47	1	4	109	1
NOT ILL	59	781	151	79	1029	226
EAR SYMPTOMS	0	4	0	1	0	1
NO EAR SYMPTOMS	61	824	152	82	1138	226
SKIN SYMPTOMS	0	3	0	1	20	0
NO SKIN SYMPTOMS	61	825	152	81	1122	227
EYE SYMPTOMS	0	1	0	4	39	0
NO EYE SYMPTOMS	61	827	152	79	1099	226
RESPIRATORY SYMPTOMS	1	23	0	0	33	0
NO RESPIRATORY SYMPTOMS	60	805	152	79	1099	226
GI SYMPTOMS	1	7	1	0	33	0
NO GI SYMPTOMS	60	8215	151	83	1105	227

Table 9.6 Continued

VARIABLE	BEACH 1 WADEDSWIM 1 (n=61)	2 (n=828)	3 (n=152)	BEACH 2 WADESWIM 1 (n=83)	2 (n=1138)	3 (n=227)
ITALIAN	41	399	75	34	483	89
NOT ITALIAN	20	429	77	49	655	138
INTERVIEWER 1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	15	166	45
4	14	133	31	7	61	8
5	0	0	0	0	0	0
6	0	0	0	8	223	49
7	25	419	12	7	96	6
8	7	54	16	15	231	36
9	0	0	0	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	15	57	25	9	149	38
13	0	165	68	1	79	9
14	0	0	0	21	133	36
SWALLOWED WATER	0	173	0	0	249	0
DID NOT SWALLOW WATER	61	655	152	83	889	227
HEAD UNDER WATER	0	687	0	0	878	0
DID NOT PUT HEAD UNDER WATER	61	141	152	83	260	227
SOCIOECONOMIC GROUP 1	41	585	111	52	773	159
2	10	107	18	12	224	39
3	10	136	23	19	141	29
FOOD 1	0	23	11	5	105	19
2	43	493	110	53	697	135
3	7	77	7	3	115	31
4	11	235	24	22	221	42
SEX MALE	19	377	71	26	558	100
FEMALE	42	451	81	57	580	127
NEWSBA 1	11	308	18	20	423	40
2	50	520	134	63	715	187
NEWCP 1	17	174	34	28	234	67
2	44	654	118	55	904	160
AVERAGE AGE	27.71	20.63	32.97	27.04	20.61	30.25

Full definitions of variables are given in Chapter 5.

Table 9.6 Continued

VARIABLE	BEACH					
	3			4		
	WADESWIM			WADESWIM		
	1 (n=158)	2 (n=2152)	3 (n=339)	1 (n=119)	2 (n=975)	3 (n=364)
ILL	8	158	8	8	123	12
NOT ILL	150	1994	331	111	852	352
EAR SYMPTOMS	1	26	0	1	20	1
NO EAR SYMPTOMS	157	2132	339	118	955	363
SKIN SYMPTOMS	0	16	0	0	15	3
NO SKIN SYMPTOMS	158	2136	339	119	960	361
EYE SYMPTOMS	1	23	1	0	12	2
NO EYE SYMPTOMS	157	2129	338	119	963	362
RESPIRATORY SYMPTOMS	3	66	3	1	58	3
NO RESPIRATORY SYMPTOMS	155	2086	336	118	917	361
GI SYMPTOMS	3	40	2	3	35	2
NO GI SYMPTOMS	155	2112	337	116	940	362

Table 9.6 Continued

VARIABLE	BEACH 3 WADESWIM 1 (n=158)	2 (n=2152)	3 (n=339)	BEACH 4 WADESWIM 1 (n=119)	2 (n=975)	3 (n=364)
ITALIAN	33	598	123	22	183	125
NOT ITALIAN	125	1554	216	97	792	239
INTERVIEWER 1	0	68	15	0	0	0
2	0	0	0	20	70	29
3	12	176	19	5	5	29
4	18	165	29	0	0	0
5	12	165	36	0	0	0
6	7	203	25	9	114	30
7	7	445	9	0	0	0
8	8	59	16	22	156	27
9	18	193	41	31	404	96
10	7	50	10	0	0	0
11	9	56	17	0	0	0
12	26	118	23	25	166	98
13	3	210	79	0	0	0
14	31	244	20	7	60	55
SWALLOWED WATER	0	499	0	0	213	0
DID NOT SWALLOW WATER	158	1653	339	119	762	364
HEAD UNDER WATER	0	1745	0	0	790	0
DID NOT PUT HEAD UNDER WATER	158	407	339	119	185	364
SOCIOECONOMIC GROUP 1	77	1410	234	79	649	233
2	53	457	56	31	205	88
3	28	285	49	9	121	43
FOOD 1	9	118	32	3	82	15
2	80	958	183	71	484	270
3	17	300	46	15	127	15
4	52	776	78	30	282	64
SEX MALE	61	1039	132	61	504	158
FEMALE	97	1113	207	58	471	206
NEWSBA 1	32	927	40	24	380	54
2	126	1225	299	95	595	310
NEWCP 1	60	475	108	38	231	99
2	98	1077	231	81	744	265
AVERAGE AGE	28.20	21.00	33.19	23.66	20.55	29.60

Full definitions of variables are given in Chapter 5.

Table 9.6 Continued

VARIABLE	BEACH 5 WADESWIM 1 (n=52)	2 (n=355)	3 (n=60)	BEACH 6 WADESWIM 1 (n=101)	2 (n=1205)	3 (n=51)
ILL	0	18	1	2	56	0
NOT ILL	52	337	59	99	1149	51
EAR SYMPTOMS	0	3	0	0	3	0
NO EAR SYMPTOMS	52	352	60	101	1202	51
SKIN SYMPTOMS	0	0	0	0	2	0
NO SKIN SYMPTOMS	52	355	60	101	1203	51
EYE SYMPTOMS	0	1	0	0	8	0
NO EYE SYMPTOMS	52	354	60	101	1197	51
RESPIRATORY SYMPTOMS	0	7	0	0	23	0
NO RESPIRATORY SYMPTOMS	52	348	60	101	1182	51
GI SYMPTOMS	0	8	1	2	21	0
NO GI SYMPTOMS	52	347	59	99	1184	51

Table 9.6 Continued

VARIABLE	BEACH 5 WADESWIM 1 (n=52)	2 (n=355)	3 (n=60)	BEACH 6 WADESWIM 1 (n=101)	2 (n=1205)	3 (n=51)
ITALIAN	8	33	7	15	182	7
NOT ITALIAN	44	322	53	86	1023	44
INTERVIEWER 1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	12	50	11	2	20	7
4	9	52	13	15	279	9
5	0	0	0	0	0	0
6	2	23	3	0	0	0
7	16	166	0	32	543	11
8	2	10	16	3	24	1
9	0	0	0	8	224	19
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
13	8	44	16	41	115	4
14	3	10	1	0	0	0
SWALLOWED WATER	0	97	0	0	461	0
DID NOT SWALLOW WATER	52	258	60	101	744	51
HEAD UNDER WATER	0	315	0	0	1113	0
DID NOT PUT HEAD UNDER WATER	52	40	60	101	92	51
SOCIOECONOMIC GROUP 1	31	228	37	78	789	36
2	11	87	14	14	229	8
3	10	40	9	9	187	7
FOOD 1	2	42	2	7	134	8
2	27	225	53	38	353	22
3	5	28	2	34	403	12
4	18	60	3	22	315	9
SEX MALE	22	1689	252	35	536	18
FEMALE	30	187	35	66	669	33
NEWSBA 1	18	135	12	28	552	11
2	34	220	48	73	653	40
NEWCP 1	18	92	15	44	269	16
2	34	283	45	57	936	35
AVERAGE AGE	29.15	20.74	34.45	26.23	19.67	33.33

Full definitions of variables are given in Chapter 5.

Table 9.7 Crude Epidemiological Data

BEACH	MONTH	DATE	AG	AGE	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3
1	6	26	97	26.2784	54	43	0	81	8	8	80	11	6
1	7	1	257	22.5798	113	144	5	120	29	103	181	31	45
1	7	2	322	22.2733	144	178	8	208	24	82	226	52	44
1	7	3	365	22.6301	156	209	21	237	30	77	250	41	74
2	6	26	274	23.4708	115	159	2	201	36	35	180	53	41
2	7	1	40	28.2750	21	19	0	34	0	6	28	6	6
2	7	2	67	25.0448	39	28	0	63	0	4	55	12	0
2	7	3	93	20.4946	46	47	6	82	0	5	67	22	4
2	7	9	128	22.2188	58	70	16	51	35	26	80	34	14
2	7	10	279	20.5986	126	153	27	160	14	78	175	54	50
2	7	16	254	22.0472	126	128	31	123	34	66	165	50	39
2	7	17	313	23.0735	153	160	47	171	30	65	234	44	35
3	6	26	243	22.1605	111	132	19	91	31	102	176	30	37
3	7	1	151	23.5563	74	77	18	51	22	60	100	27	24
3	7	2	194	20.9639	85	109	13	51	42	88	140	32	22
3	7	3	213	23.6009	95	118	26	84	27	76	142	34	37
3	7	9	55	29.8909	24	31	2	24	12	17	33	22	0
3	7	10	275	21.2545	104	171	13	148	35	79	175	56	44
3	7	16	215	22.8465	98	117	12	105	34	64	148	32	35
3	7	17	296	23.1047	131	165	7	156	18	115	207	56	33
3	7	23	142	22.1620	81	61	13	68	12	49	71	46	25
3	7	24	180	22.4944	88	92	19	97	23	41	106	50	24
3	7	30	78	24.7949	37	41	0	50	4	24	52	20	6
3	7	31	6	16.5000	2	4	0	0	6	0	0	6	0
3	8	1	124	28.7097	52	72	14	83	13	14	70	36	18
3	8	6	130	22.9769	69	61	0	61	14	55	88	22	20
3	8	7	141	23.0284	84	57	3	75	16	47	95	27	19
3	8	13	32	23.9375	17	15	0	15	6	11	17	10	5
3	8	14	39	25.8205	17	22	0	21	18	0	30	7	2
3	8	20	44	18.6136	19	25	0	10	5	29	23	13	8
3	8	21	39	24.6410	20	19	0	13	8	18	24	12	3
3	8	27	15	24.0667	9	6	0	9	2	4	10	5	0
3	8	28	37	18.6216	15	22	0	9	15	13	14	23	0
4	6	26	134	21.5224	69	65	17	58	19	40	88	18	28
4	7	1	110	21.7636	60	50	3	48	17	42	81	11	18
4	7	2	144	21.5069	74	70	10	77	22	35	102	24	18
4	7	3	116	23.8103	54	62	14	46	10	46	84	24	8
4	7	9	77	22.5974	42	35	4	39	13	21	51	16	10
4	7	10	155	22.6516	69	86	10	80	14	51	112	27	16
4	7	16	110	24.2909	58	52	0	51	21	38	70	27	13
4	7	17	128	25.4844	67	61	9	78	15	26	93	19	16
4	7	23	127	23.7008	71	56	2	88	7	30	58	67	2
4	7	24	302	22.7285	133	169	28	219	17	38	197	61	44
4	7	30	55	25.9818	26	29	3	41	2	9	25	30	0
5	7	30	180	23.2333	78	102	25	106	18	31	112	44	24
5	8	1	287	23.5645	137	150	21	199	17	50	184	68	35

Table 9.7 Continued

BEACH	MONTH	DATE	AG	AGE	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3
6	8	6	303	19.8020	129	174	54	84	77	88	214	39	50
6	8	7	374	21.4759	153	221	25	117	118	114	239	63	72
6	8	13	85	22.4588	41	44	0	15	40	30	62	13	10
6	8	14	165	20.3515	82	83	27	42	85	11	110	33	22
6	8	20	93	18.4624	43	50	12	28	31	22	54	25	14
6	8	21	200	21.6700	87	113	9	88	46	57	134	41	25
6	8	27	59	18.5424	27	32	3	16	34	6	37	17	5
6	8	28	78	20.6282	27	51	19	23	18	18	53	20	5

Table 9.7 Continued

BEACH	MONTH	DATE	NEWCP1	NEWCP2	ITAL1	ITAL2	WADESWM1	WADESWM2	WADESWM3
1	6	26	17	80	42	55	15	57	25
1	7	1	56	201	99	158	28	208	21
1	7	2	74	248	146	176	8	262	52
1	7	3	78	287	228	137	10	301	54
2	6	26	62	212	119	155	15	236	23
2	7	1	7	33	10	30	1	31	8
2	7	2	12	55	40	27	3	50	14
2	7	3	17	76	60	33	5	72	16
2	7	9	32	96	39	89	5	79	44
2	7	10	66	213	85	194	19	211	49
2	7	16	68	186	84	170	8	220	26
2	7	17	65	248	169	144	27	239	47
3	6	26	68	175	85	158	18	184	41
3	7	1	44	107	29	122	11	127	13
3	7	2	52	142	32	162	6	167	21
3	7	3	53	160	90	123	10	183	20
3	7	9	14	41	7	48	3	40	12
3	7	10	64	211	136	139	7	229	39
3	7	16	47	168	40	175	3	203	9
3	7	17	68	228	108	188	4	271	21
3	7	23	31	111	57	85	8	112	22
3	7	24	42	138	57	123	14	107	59
3	7	30	14	64	12	66	21	52	5
3	7	31	1	5	0	6	0	5	1
3	8	1	26	98	18	106	7	83	34
3	8	6	31	99	18	112	11	108	11
3	8	7	34	107	38	103	11	122	8
3	8	13	8	24	6	26	3	25	4
3	8	14	13	26	0	39	4	28	7
3	8	20	10	34	1	43	8	31	5
3	8	21	11	28	7	32	6	29	4
3	8	27	4	11	0	15	1	13	1
3	8	28	8	29	13	24	2	33	2
4	6	26	44	90	34	100	6	118	10
4	7	1	31	79	8	102	9	78	23
4	7	2	42	102	20	124	7	117	20
4	7	3	35	81	9	107	15	91	10
4	7	9	22	55	13	64	13	47	17
4	7	10	36	119	78	77	0	104	51
4	7	16	25	85	16	94	10	94	6
4	7	17	28	100	18	110	8	98	22
4	7	23	32	95	26	101	19	53	55
4	7	24	61	241	92	210	25	168	109
4	7	30	12	43	16	39	7	7	41
5	7	30	41	139	13	167	13	158	9
5	8	1	64	223	35	252	39	197	51

Table 9.7 Continued

BEACH	MONTH	DATE	NEWCP1	NEWCP2	ITAL1	ITAL2	WADESWM1	WADESWM2	WADESWM3
6	8	6	77	226	60	243	23	273	7
6	8	7	91	283	64	310	35	332	7
6	8	13	19	66	6	79	3	74	8
6	8	14	39	126	18	147	14	150	1
6	8	20	23	70	5	88	12	78	3
6	8	21	48	152	42	158	10	177	13
6	8	27	13	46	4	55	2	53	4
6	8	28	19	59	5	73	2	68	8

Table 9.7 Continued

BEACH	MONTH	DATE	AG	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
1	6	26	97	0	0	0	0	0	0	0
1	7	1	257	0	0	0	0	0	0	180
1	7	2	322	0	0	0	88	0	0	125
1	7	3	365	0	0	0	90	0	0	151
2	6	26	274	0	0	0	76	0	0	109
2	7	1	40	0	0	0	0	0	4	0
2	7	2	67	0	0	0	0	0	0	0
2	7	3	93	0	0	0	0	0	0	0
2	7	9	128	0	0	39	0	0	33	0
2	7	10	279	0	0	36	0	0	93	0
2	7	16	254	0	0	89	0	0	66	0
2	7	17	313	0	0	62	0	0	84	0
3	6	26	243	83	0	0	0	0	0	0
3	7	1	151	0	0	57	0	0	56	0
3	7	2	194	0	0	62	0	0	79	0
3	7	3	213	0	0	69	0	0	100	0
3	7	9	55	0	0	0	17	10	0	0
3	7	10	275	0	0	0	57	50	0	101
3	7	16	215	0	0	0	35	37	0	92
3	7	17	296	0	0	0	52	58	0	114
3	7	23	142	0	0	0	21	23	0	57
3	7	24	180	0	0	0	26	35	0	68
3	7	30	78	0	0	0	0	0	0	0
3	7	31	6	0	0	0	0	0	0	0
3	8	1	124	0	0	0	0	0	0	0
3	8	6	130	0	0	0	0	0	0	0
3	8	7	141	0	0	0	0	0	0	0
3	8	13	32	0	0	0	0	0	0	0
3	8	14	39	0	0	0	0	0	0	0
3	8	20	44	0	0	0	0	0	0	0
3	8	21	39	0	0	0	0	0	0	0
3	8	27	15	0	0	0	0	0	0	15
3	8	28	37	0	0	19	4	0	0	14
4	6	26	134	0	0	0	0	0	57	0
4	7	1	110	0	0	0	0	0	0	0
4	7	2	144	0	0	0	0	0	0	0
4	7	3	116	0	0	0	0	0	0	0
4	7	9	77	0	0	0	0	0	0	0
4	7	10	155	0	0	0	0	0	0	0
4	7	16	110	0	0	0	0	0	0	0
4	7	17	128	0	0	0	0	0	0	0
4	7	23	127	0	30	11	0	0	16	0
4	7	24	302	0	89	0	0	0	65	0
4	7	30	55	0	0	28	0	0	15	0
5	7	30	180	0	0	8	46	0	4	104
5	8	1	287	0	0	65	28	0	24	78

Table 9.7 Continued

BEACH	MONTH	DATE	AG	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
6	8	6	303	0	0	0	92	0	0	120
6	8	7	374	0	0	0	67	0	0	139
6	8	13	85	0	0	0	0	0	0	0
6	8	14	165	0	0	0	55	0	0	110
6	8	20	93	0	0	0	26	0	0	39
6	8	21	200	0	0	0	24	0	0	109
6	8	27	59	0	0	0	13	0	0	46
6	8	28	78	0	0	29	26	0	0	23

Table 9.7 Continued

BEACH	MONTH	DATE	AG	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
1	6	26	97	0	0	0	0	97	0	0
1	7	1	257	77	0	0	0	0	0	0
1	7	2	322	0	0	0	0	0	109	0
1	7	3	365	0	0	0	0	0	124	0
2	6	26	274	0	0	0	0	0	89	0
2	7	1	40	0	0	0	0	36	0	0
2	7	2	67	0	0	0	0	67	0	0
2	7	3	93	0	0	0	0	93	0	0
2	7	9	128	32	0	0	0	0	0	24
2	7	10	279	87	0	0	0	0	0	63
2	7	16	254	66	0	0	0	0	0	33
2	7	17	313	97	0	0	0	0	0	70
3	6	26	243	0	78	0	82	0	0	0
3	7	1	151	0	0	0	0	0	0	38
3	7	2	194	0	0	0	0	0	0	53
3	7	3	213	0	0	0	0	0	0	44
3	7	9	55	0	0	0	0	0	28	0
3	7	10	275	0	0	0	0	0	67	0
3	7	16	215	0	0	0	0	0	51	0
3	7	17	296	0	0	0	0	0	72	0
3	7	23	142	0	0	0	0	0	41	0
3	7	24	180	18	0	0	0	0	33	0
3	7	30	78	0	0	0	0	78	0	0
3	7	31	6	0	0	0	0	6	0	0
3	8	1	124	0	84	0	0	40	0	0
3	8	6	130	0	60	0	0	43	0	27
3	8	7	141	65	0	0	0	0	0	76
3	8	13	32	0	0	32	0	0	0	0
3	8	14	39	0	4	35	0	0	0	0
3	8	20	44	0	26	0	0	0	0	18
3	8	21	39	0	0	0	0	0	0	39
3	8	27	15	0	0	0	0	0	0	0
3	8	28	37	0	0	0	0	0	0	0
4	6	26	134	53	0	0	0	0	0	24
4	7	1	110	0	110	0	0	0	0	0
4	7	2	144	66	78	0	0	0	0	0
4	7	3	116	61	55	0	0	0	0	0
4	7	9	77	0	51	0	0	26	0	0
4	7	10	155	0	91	0	0	64	0	0
4	7	16	110	0	67	0	0	43	0	0
4	7	17	128	4	79	0	0	45	0	0
4	7	23	127	15	0	0	0	37	0	18
4	7	24	302	0	0	0	0	74	0	74
4	7	30	55	6	0	0	0	0	0	6
5	7	30	180	4	0	0	0	0	0	14
5	8	1	287	24	0	0	0	0	68	0

Table 9.7 Continued

BEACH	MONTH	DATE	AG	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
6	8	6	303	0	0	0	0	0	91	0
6	8	7	374	0	99	0	0	0	69	0
6	8	13	85	0	85	0	0	0	0	0
6	8	14	165	0	0	0	0	0	0	0
6	8	20	93	28	0	0	0	0	0	0
6	8	21	200	0	67	0	0	0	0	0
6	8	27	59	0	0	0	0	0	0	0
6	8	28	78	0	0	0	0	0	0	0

Table 9.7 Continued

BEACH	MONTH	DATE	AG	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2
1	6	26	97	12	85	50	47	13	84
1	7	1	257	93	164	185	72	36	221
1	7	2	322	100	222	209	113	52	270
1	7	3	365	132	233	243	122	72	293
2	6	26	274	48	226	186	88	88	186
2	7	1	40	13	27	30	10	1	39
2	7	2	67	18	49	45	22	2	65
2	7	3	93	8	85	55	38	6	87
2	7	9	128	54	74	69	59	16	112
2	7	10	279	74	205	157	122	35	244
2	7	16	254	138	116	166	88	60	194
2	7	17	313	130	183	170	143	41	272
3	6	26	243	76	167	155	88	57	186
3	7	1	151	82	69	92	59	21	130
3	7	2	194	99	95	130	64	39	155
3	7	3	213	65	148	129	84	26	187
3	7	9	55	23	32	28	27	11	44
3	7	10	275	71	204	181	94	57	218
3	7	16	215	139	76	179	36	64	151
3	7	17	296	123	173	235	61	73	223
3	7	23	142	37	105	92	50	15	127
3	7	24	180	32	148	88	92	27	153
3	7	30	78	16	62	47	31	13	65
3	7	31	6	4	2	5	1	5	1
3	8	1	124	50	74	65	59	34	90
3	8	6	130	54	76	103	27	14	116
3	8	7	141	55	86	87	54	7	134
3	8	13	32	17	15	19	13	2	30
3	8	14	39	10	29	16	23	1	38
3	8	20	44	17	27	25	19	13	31
3	8	21	39	6	33	25	14	1	38
3	8	27	15	4	11	13	2	8	7
3	8	28	37	19	18	31	6	11	26
4	6	26	134	63	71	90	44	23	111
4	7	1	110	42	68	56	54	26	84
4	7	2	144	66	78	97	47	46	98
4	7	3	116	61	55	82	34	22	94
4	7	9	77	25	52	36	41	2	75
4	7	10	155	19	136	76	79	19	136
4	7	16	110	40	70	78	32	12	98
4	7	17	128	28	100	81	47	25	103
4	7	23	127	31	96	44	83	8	119
4	7	24	302	69	233	145	157	27	275
4	7	30	55	14	41	5	50	3	52
5	7	30	180	61	119	141	39	49	131
5	8	1	287	104	183	174	113	48	239

Table 9.7 Continued

BEACH	MONTH	DATE	AG	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2
6	8	6	303	121	182	253	50	111	192
6	8	7	374	159	215	298	76	105	269
6	8	13	85	55	30	70	15	50	35
6	8	14	165	67	98	145	20	52	113
6	8	20	93	34	59	75	18	35	58
6	8	21	200	89	111	163	37	66	134
6	8	27	59	35	24	50	9	21	38
6	8	28	78	31	47	59	19	21	57

Table 9.7 Continued

BEACH	MONTH	DATE	AGE	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
1	6	26	26.2784	4	93	1	96	3	94
1	7	1	22.5798	11	246	3	254	5	252
1	7	2	22.2733	16	306	1	321	6	316
1	7	3	22.6301	19	346	4	361	10	355
2	6	26	23.4708	15	259	5	269	4	270
2	7	1	28.2750	0	40	0	40	0	40
2	7	2	25.0448	2	65	1	66	1	66
2	7	3	20.4946	5	88	4	89	2	91
2	7	9	22.2188	7	121	2	126	2	126
2	7	10	20.5986	19	260	2	277	7	272
2	7	16	22.0472	35	219	13	241	18	236
2	7	17	23.0735	31	282	6	307	10	303
3	6	26	22.1605	17	226	4	239	6	237
3	7	1	23.5563	17	134	7	144	5	146
3	7	2	20.9639	26	168	9	185	17	177
3	7	3	23.6009	21	192	6	207	7	206
3	7	9	29.8909	3	52	1	54	0	55
3	7	10	21.2545	11	264	1	274	6	269
3	7	16	22.8465	13	202	5	210	3	212
3	7	17	23.1047	20	276	3	293	7	289
3	7	23	22.1620	6	136	0	142	3	139
3	7	24	22.4944	6	174	1	179	3	177
3	7	30	24.7949	4	74	2	76	2	76
3	7	31	16.5000	0	6	0	6	0	6
3	8	1	28.7097	4	120	0	124	2	122
3	8	6	22.9769	4	126	2	128	1	129
3	8	7	23.0284	8	133	1	140	4	137
3	8	13	23.9375	1	31	0	32	0	32
3	8	14	25.8205	0	39	0	39	0	39
3	8	20	18.6136	1	43	1	43	0	44
3	8	21	24.6410	5	34	1	38	3	36
3	8	27	24.0667	3	12	1	14	1	14
3	8	28	18.6216	4	33	0	37	2	35
4	6	26	21.5224	18	116	6	128	3	131
4	7	1	21.7636	22	88	1	109	14	96
4	7	2	21.5069	33	111	2	142	20	124
4	7	3	23.8103	21	95	11	105	8	108
4	7	9	22.5974	6	71	1	76	2	75
4	7	10	22.6516	6	149	2	153	2	153
4	7	16	24.2909	6	104	4	106	2	108
4	7	17	25.4844	8	120	4	124	5	123
4	7	23	23.7008	6	121	3	124	0	127
4	7	24	22.7285	15	287	6	296	5	297
4	7	30	25.9818	2	53	0	55	1	54
5	7	30	23.2333	6	174	0	180	5	175
5	8	1	23.5645	13	274	9	278	2	285

Table 9.7 Continued

BEACH	MONTH	DATE	AGE	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
6	8	6	19.8020	9	294	7	296	2	301
6	8	7	21.4759	20	354	11	363	8	366
6	8	13	22.4588	3	82	0	85	2	83
6	8	14	20.3515	5	160	0	165	2	163
6	8	20	18.4624	7	86	0	93	3	90
6	8	21	21.6700	6	194	3	197	2	198
6	8	27	18.5424	5	54	2	57	3	56
6	8	28	20.6282	3	75	0	78	1	77

Table 9.7 Continued

BEACH	MONTH	DATE	AGE	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
1	6	26	26.2784	0	97	1	96	0	97
1	7	1	22.5798	1	256	0	257	2	255
1	7	2	22.2733	1	321	0	322	1	321
1	7	3	22.6301	1	364	0	365	1	364
2	6	26	23.4708	0	274	2	272	3	271
2	7	1	28.2750	0	40	0	40	0	40
2	7	2	25.0448	0	67	0	67	0	67
2	7	3	20.4946	2	91	0	93	0	93
2	7	9	22.2188	0	128	2	126	4	124
2	7	10	20.5986	4	275	3	276	1	278
2	7	16	22.0472	7	247	3	251	3	251
2	7	17	23.0735	8	305	8	305	5	308
3	6	26	22.1605	4	239	3	240	1	242
3	7	1	23.5563	1	150	1	150	3	148
3	7	2	20.9639	2	192	4	190	4	190
3	7	3	23.6009	2	211	1	212	3	210
3	7	9	29.8909	0	55	2	53	0	55
3	7	10	21.2545	2	273	0	275	0	275
3	7	16	22.8465	1	214	1	214	3	212
3	7	17	23.1047	1	295	8	288	0	296
3	7	23	22.1620	0	142	0	142	2	140
3	7	24	22.4944	0	180	0	180	1	179
3	7	30	24.7949	0	78	1	77	0	78
3	7	31	16.5000	0	6	0	6	0	6
3	8	1	28.7097	0	124	0	124	2	122
3	8	6	22.9769	0	130	0	130	0	130
3	8	7	23.0284	1	140	3	138	1	140
3	8	13	23.9375	0	32	0	32	1	31
3	8	14	25.8205	0	39	0	39	0	39
3	8	20	18.6136	0	44	0	44	0	44
3	8	21	24.6410	1	38	1	38	0	39
3	8	27	24.0667	1	14	0	15	0	15
3	8	28	18.6216	0	37	0	37	0	37
4	6	26	21.5224	5	129	1	133	2	132
4	7	1	21.7636	0	110	1	109	5	105
4	7	2	21.5069	4	140	6	138	5	139
4	7	3	23.8103	2	114	3	113	2	114
4	7	9	22.5974	3	74	0	77	0	77
4	7	10	22.6516	0	155	1	154	1	154
4	7	16	24.2909	0	110	1	109	0	110
4	7	17	25.4844	1	127	0	128	4	124
4	7	23	23.7008	1	126	0	127	0	127
4	7	24	22.7285	1	301	1	301	3	299
4	7	30	25.9818	1	54	0	55	0	55
5	7	30	23.2333	0	180	0	180	2	178
5	8	1	23.5645	0	287	1	286	1	286

Table 9.7 Continued

BEACH	MONTH	DATE	AGE	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
6	8	6	19.8020	0	303	1	302	0	303
6	8	7	21.4759	0	374	2	372	2	372
6	8	13	22.4588	1	84	0	85	0	85
6	8	14	20.3515	0	165	2	163	0	165
6	8	20	18.4624	1	92	2	91	0	93
6	8	21	21.6700	0	200	0	200	1	199
6	8	27	18.5424	0	59	0	59	0	59
6	8	28	20.6282	0	78	1	77	0	78

Table 9.7 Continued

Legend:

Beach: see Table 9.1

Ag: number of persons

Sex: 1 - male, 2- female

Food: 1 - no food and/or drink consumed at beach
2 - food and/or drink brought from home and consumed at beach
3 - food and/or drink bought at beach and consumed at beach
4 - food and/or drink brought from home and bought at beach consumed on beach

Newse1 - high SES (SocioEconomic Status)
Newse2 - middle SES
Newse3 - low SES (see Table 5.8)

Newcp1 - number of contact persons
Newcp2 - number of non-contact persons

Ital1 - number of italians
Ital2 - number of non-Italians

Wadeswm1 - number of waders
Wadeswm2 - number of swimmers
Wadeswm3 - number of persons who did not enter the water

Interv1-14 - interviewers

Newsba1 - number of persons who swam or went in the water 4 days before, or 3 days after the interview day
Newsba2 - number of persons who did not swim or go into the water 4 days before, or 3 days after the interview day

Headund1 - number of persons who put their head under the water
Headund2 - number of persons who did not put their heads under the water

Table 9.7 Continued

Legend:

Swallow1 - number of persons who swallowed water
Swallow2 - number of persons who did not swallow water
Newill1 - number of ill persons
Newill2 - number of persons not ill

Newgi1 - number of persons with GI symptoms
Newgi2 - number of persons without GI symptoms

Newres1 - number of persons with respiratory symptoms
Newres2 - number of persons with no respiratory symptoms

Newskin1 - number of persons with skin problems
Newskin2 - number of persons with no skin problems

Neweye1 - number of persons with eye problems
Neweye2 - Number of persons without eye problems

Newear1 - number of persons with ear problems
Newear2 - number of persons without ear problems

Table 9.8 Crude Epidemiological Data for Swimmers, Waders, and Persons Who Did Not Enter the Water

BEACH	WADESWIM	MONTH	DATE	N	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3	ITAL1	ITAL2
1	1	6	26	15	5	10	0	14	1	0	14	1	0	10	5
1	1	7	1	28	8	20	0	16	6	6	19	4	5	16	12
1	1	7	2	8	3	5	0	4	0	4	5	2	1	6	2
1	1	7	3	10	3	7	0	9	0	1	3	3	4	9	1
1	2	6	26	57	33	24	0	51	4	2	44	10	3	29	28
1	2	7	1	208	95	113	4	91	21	92	148	25	35	81	127
1	2	7	2	262	122	140	8	161	23	70	185	45	32	109	153
1	2	7	3	301	127	174	11	190	29	71	208	27	66	180	121
1	3	6	26	25	16	9	0	16	3	6	22	0	3	3	22
1	3	7	1	21	10	11	1	13	2	5	14	2	5	2	19
1	3	7	2	52	19	33	0	43	1	8	36	5	11	31	21
1	3	7	3	54	26	28	10	38	1	5	39	11	4	39	15
2	1	6	26	15	4	11	0	13	1	1	6	3	6	2	13
2	1	7	1	1	0	1	0	1	0	0	1	0	0	0	1
2	1	7	2	3	0	3	0	3	0	0	2	1	0	1	2
2	1	7	3	5	3	2	0	5	0	0	0	5	0	5	0
2	1	7	9	5	0	5	0	2	0	3	2	3	0	0	5
2	1	7	10	19	9	10	1	8	2	8	16	0	3	3	16
2	1	7	16	8	1	7	0	5	0	3	7	0	1	2	6
2	1	7	17	27	9	18	4	16	0	7	18	0	9	21	6
2	2	6	26	236	101	135	2	172	32	30	157	47	32	106	130
2	2	7	1	31	18	13	0	25	0	6	21	6	4	9	22
2	2	7	2	50	31	19	0	46	0	4	40	10	0	32	18
2	2	7	3	72	38	34	6	61	0	5	51	17	4	42	30
2	2	7	9	79	38	41	14	36	19	10	56	12	11	33	46
2	2	7	10	211	100	111	16	124	11	60	125	51	35	68	143
2	2	7	16	220	113	107	31	105	29	55	144	39	37	72	148
2	2	7	17	239	119	120	36	128	24	51	179	42	18	121	118
2	3	6	26	23	10	13	0	16	3	4	17	3	3	11	12
2	3	7	1	8	3	5	0	8	0	0	6	0	2	1	7
2	3	7	2	14	8	6	0	14	0	0	13	1	0	7	7
2	3	7	3	16	5	11	0	16	0	0	16	0	0	13	3
2	3	7	9	44	20	24	2	13	16	13	22	19	3	6	38
2	3	7	10	49	17	32	10	28	1	10	34	3	12	14	35
2	3	7	16	26	12	14	0	13	5	8	14	11	1	10	16
2	3	7	17	47	25	22	7	27	6	7	37	2	8	27	20
3	1	6	26	18	7	11	0	10	0	8	12	1	5	6	12
3	1	7	1	11	4	7	0	4	2	5	7	2	2	3	8
3	1	7	2	6	3	3	0	3	2	1	3	2	1	1	5
3	1	7	3	10	6	4	0	7	0	3	3	3	4	2	8
3	1	7	9	3	1	2	1	2	0	0	1	2	0	0	3
3	1	7	10	7	1	6	0	6	0	1	6	1	0	5	2
3	1	7	16	3	0	3	0	1	0	2	1	1	1	2	1
3	1	7	17	4	1	3	0	2	0	2	1	3	0	1	3
3	1	7	23	8	6	2	4	4	0	0	2	2	4	0	8
3	1	7	24	14	4	10	4	7	3	0	4	8	2	6	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3	ITAL1	ITAL2
3	1	7	30	21	7	14	0	15	0	6	16	5	0	2	19
3	1	8	1	7	1	6	0	7	0	0	1	5	1	0	7
3	1	8	6	11	8	3	0	1	1	9	5	1	5	1	10
3	1	8	7	11	3	8	0	5	3	3	5	5	1	1	10
3	1	8	13	3	1	2	0	1	0	2	3	0	0	0	3
3	1	8	14	4	1	3	0	0	4	0	2	2	0	0	4
3	1	8	20	8	3	5	0	0	0	8	2	4	2	1	7
3	1	8	21	6	4	2	0	2	2	2	2	4	0	0	6
3	1	8	27	1	0	1	0	1	0	0	1	0	0	0	1
3	1	8	28	2	0	2	0	2	0	0	0	2	0	2	0
3	2	6	26	184	87	97	14	64	24	82	135	25	24	57	127
3	2	7	1	127	66	61	17	39	19	52	87	20	20	20	107
3	2	7	2	167	74	93	10	42	36	79	119	29	19	24	143
3	2	7	3	183	80	103	21	72	24	66	126	27	30	77	106
3	2	7	9	40	19	21	1	17	9	13	26	14	0	5	35
3	2	7	10	229	91	138	13	110	31	75	146	48	35	111	118
3	2	7	16	203	94	109	11	98	33	61	138	31	34	35	168
3	2	7	17	271	123	148	4	144	16	107	187	51	33	103	168
3	2	7	23	112	67	45	7	54	10	41	58	36	18	49	63
3	2	7	24	107	57	50	7	51	12	37	59	30	18	27	80
3	2	7	30	52	27	25	0	34	4	14	31	15	6	6	46
3	2	7	31	5	2	3	0	0	5	0	0	5	0	0	5
3	2	8	1	83	41	42	10	55	10	8	47	29	7	13	70
3	2	8	6	108	58	50	0	56	11	41	72	21	15	15	93
3	2	8	7	122	77	45	3	63	12	44	85	22	15	33	89
3	2	8	13	25	15	10	0	10	6	9	11	10	4	6	19
3	2	8	14	28	13	15	0	18	10	0	25	3	0	0	28
3	2	8	20	31	13	18	0	7	5	19	18	8	5	0	31
3	2	8	21	29	13	16	0	10	6	13	19	8	2	6	23
3	2	8	27	13	8	5	0	7	2	4	9	4	0	0	13
3	2	8	28	33	14	19	0	7	15	11	12	21	0	11	22
3	3	6	26	41	17	24	5	17	7	12	29	4	8	22	19
3	3	7	1	13	4	9	1	8	1	3	6	5	2	6	7
3	3	7	2	21	8	13	3	6	4	8	18	1	2	7	14
3	3	7	3	20	9	11	5	5	3	7	13	4	3	11	9
3	3	7	9	12	4	8	0	5	3	4	6	6	0	2	10
3	3	7	10	39	12	27	0	32	4	3	23	7	9	20	19
3	3	7	16	9	4	5	1	6	1	1	9	0	0	3	6
3	3	7	17	21	7	14	3	10	2	6	19	2	0	4	17
3	3	7	23	22	8	14	2	10	2	8	11	8	3	8	14
3	3	7	24	59	27	32	8	39	8	4	43	12	4	24	35
3	3	7	30	5	3	2	0	1	0	4	5	0	0	4	1
3	3	7	31	1	0	1	0	0	1	0	0	1	0	0	1
3	3	8	1	34	10	24	4	21	3	6	22	2	10	5	29
3	3	8	6	11	3	8	0	4	2	5	11	0	0	2	9
3	3	8	7	8	4	4	0	7	1	0	5	0	3	4	4

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3	ITAL1	ITAL2
3	3	8	13	4	1	3	0	4	0	0	3	0	1	0	4
3	3	8	14	7	3	4	0	3	4	0	3	2	2	0	7
3	3	8	20	5	3	2	0	3	0	2	3	1	1	0	5
3	3	8	21	4	3	1	0	1	0	3	3	0	1	1	3
3	3	8	27	1	1	0	0	1	0	0	0	1	0	0	1
3	3	8	28	2	1	1	0	0	0	2	2	0	0	0	2
4	1	6	26	6	1	5	1	1	2	2	4	1	1	2	4
4	1	7	1	9	5	4	0	2	4	3	8	0	1	0	9
4	1	7	2	7	3	4	0	4	0	3	5	2	0	3	4
4	1	7	3	15	7	8	0	7	1	7	11	3	1	2	13
4	1	7	9	13	8	5	0	6	4	3	10	3	0	9	4
4	1	7	16	10	4	6	0	7	0	3	7	0	3	1	9
4	1	7	17	8	4	4	0	6	0	2	4	4	0	1	7
4	1	7	23	19	11	8	0	12	4	3	8	9	2	0	19
4	1	7	24	25	12	13	0	21	0	4	17	7	1	4	21
4	1	7	30	7	6	1	2	5	0	0	5	2	0	0	7
4	2	6	26	118	64	54	14	52	16	36	78	17	23	31	87
4	2	7	1	78	43	35	3	30	10	35	55	8	15	4	74
4	2	7	2	117	61	56	9	63	18	27	84	21	12	12	105
4	2	7	3	91	45	46	14	33	9	35	67	18	6	4	87
4	2	7	9	47	25	22	4	20	9	14	32	9	6	2	45
4	2	7	10	104	43	61	10	42	14	38	75	19	10	43	61
4	2	7	16	94	54	40	0	40	19	35	60	25	9	14	80
4	2	7	17	98	57	41	7	58	14	19	73	11	14	12	86
4	2	7	23	53	29	24	0	30	3	20	19	34	0	6	47
4	2	7	24	168	79	89	21	109	15	23	102	40	26	55	113
4	2	7	30	7	4	3	0	7	0	0	4	3	0	0	7
4	3	6	26	10	4	6	2	5	1	2	6	0	4	1	9
4	3	7	1	23	12	11	0	16	3	4	18	3	2	4	19
4	3	7	2	20	10	10	1	10	4	5	13	1	6	5	15
4	3	7	3	10	2	8	0	6	0	4	6	3	1	3	7
4	3	7	9	17	9	8	0	13	0	4	9	4	4	2	15
4	3	7	10	51	26	25	0	38	0	13	37	8	6	35	16
4	3	7	16	6	0	6	0	4	2	0	3	2	1	1	5
4	3	7	17	22	6	16	2	14	1	5	16	4	2	5	17
4	3	7	23	55	31	24	2	46	0	7	31	24	0	20	35
4	3	7	24	109	42	67	7	89	2	11	78	14	17	33	76
4	3	7	30	41	16	25	1	29	2	9	16	25	0	16	25
5	1	7	30	13	5	8	1	9	0	3	7	4	2	0	13
5	1	8	1	39	17	22	1	18	5	15	24	7	8	8	31
5	2	7	30	158	69	89	23	90	18	27	99	39	20	13	145
5	2	8	1	197	99	98	19	135	10	33	129	48	20	20	177
5	3	7	30	9	4	5	1	7	0	1	6	1	2	0	9
5	3	8	1	51	21	30	1	46	2	2	31	13	7	7	44
6	1	8	6	23	5	18	4	9	4	6	16	4	3	5	18
6	1	8	7	35	14	21	0	15	10	10	30	3	2	4	31

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	SEX1	SEX2	FOOD1	FOOD2	FOOD3	FOOD4	NEWSE1	NEWSE2	NEWSE3	ITAL1	ITAL2
6	1	8	13	3	1	2	0	0	3	0	3	0	0	0	3
6	1	8	14	14	8	6	2	7	4	1	12	0	2	5	9
6	1	8	20	12	3	9	0	4	5	3	9	3	0	1	11
6	1	8	21	10	3	7	0	2	6	2	6	2	2	0	10
6	1	8	27	2	0	2	1	1	0	0	0	2	0	0	2
6	1	8	28	2	1	1	0	0	2	0	2	0	0	0	2
6	2	8	6	273	123	150	49	69	73	82	191	35	47	54	219
6	2	8	7	332	137	195	25	99	107	101	205	60	67	60	272
6	2	8	13	74	36	38	0	13	35	26	54	13	7	6	68
6	2	8	14	150	74	76	25	34	81	10	97	33	20	13	137
6	2	8	20	78	40	38	12	23	25	18	43	21	14	4	74
6	2	8	21	177	77	100	9	80	34	54	121	33	23	39	138
6	2	8	27	53	27	26	2	12	33	6	34	14	5	1	52
6	2	8	28	68	22	46	12	23	15	18	44	20	4	5	63
6	3	8	6	7	1	6	1	6	0	0	7	0	0	1	6
6	3	8	7	7	2	5	0	3	1	3	4	0	3	0	7
6	3	8	13	8	4	4	0	2	2	4	5	0	3	0	8
6	3	8	14	1	0	1	0	1	0	0	1	0	0	0	1
6	3	8	20	3	0	3	0	1	1	1	2	1	0	0	3
6	3	8	21	13	7	6	0	6	6	1	7	6	0	3	10
6	3	8	27	4	0	4	0	3	1	0	3	1	0	3	1
6	3	8	28	8	4	4	7	0	1	0	7	0	1	0	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
1	1	6	26	15	0	0	0	0	0	0	0
1	1	7	1	28	0	0	0	0	0	0	21
1	1	7	2	8	0	0	0	5	0	0	3
1	1	7	3	10	0	0	0	9	0	0	1
1	2	6	26	57	0	0	0	0	0	0	0
1	2	7	1	208	0	0	0	0	0	0	154
1	2	7	2	262	0	0	0	65	0	0	116
1	2	7	3	301	0	0	0	68	0	0	149
1	3	6	26	25	0	0	0	0	0	0	0
1	3	7	1	21	0	0	0	0	0	0	5
1	3	7	2	52	0	0	0	18	0	0	6
1	3	7	3	54	0	0	0	13	0	0	1
2	1	6	26	15	0	0	0	7	0	0	7
2	1	7	1	1	0	0	0	0	0	0	0
2	1	7	2	3	0	0	0	0	0	0	0
2	1	7	3	5	0	0	0	0	0	0	0
2	1	7	9	5	0	0	4	0	0	0	0
2	1	7	10	19	0	0	1	0	0	4	0
2	1	7	16	8	0	0	4	0	0	0	0
2	1	7	17	27	0	0	6	0	0	4	0
2	2	6	26	236	0	0	0	61	0	0	96
2	2	7	1	31	0	0	0	0	0	4	0
2	2	7	2	50	0	0	0	0	0	0	0
2	2	7	3	72	0	0	0	0	0	0	0
2	2	7	9	79	0	0	24	0	0	19	0
2	2	7	10	211	0	0	29	0	0	76	0
2	2	7	16	220	0	0	73	0	0	61	0
2	2	7	17	239	0	0	40	0	0	63	0
2	3	6	26	23	0	0	0	8	0	0	6
2	3	7	1	8	0	0	0	0	0	0	0
2	3	7	2	14	0	0	0	0	0	0	0
2	3	7	3	16	0	0	0	0	0	0	0
2	3	7	9	44	0	0	11	0	0	14	0
2	3	7	10	49	0	0	6	0	0	13	0
2	3	7	16	26	0	0	12	0	0	5	0
2	3	7	17	47	0	0	16	0	0	17	0
3	1	6	26	18	0	0	0	0	0	0	0
3	1	7	1	11	0	0	5	0	0	2	0
3	1	7	2	6	0	0	4	0	0	0	0
3	1	7	3	10	0	0	3	0	0	5	0
3	1	7	9	3	0	0	0	3	0	0	0
3	1	7	10	7	0	0	0	5	1	0	1
3	1	7	16	3	0	0	0	2	0	0	1
3	1	7	17	4	0	0	0	2	2	0	0
3	1	7	23	8	0	0	0	0	4	0	2
3	1	7	24	14	0	0	0	6	5	0	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
3	1	7	30	21	0	0	0	0	0	0	0
3	1	8	1	7	0	0	0	0	0	0	0
3	1	8	6	11	0	0	0	0	0	0	0
3	1	8	7	11	0	0	0	0	0	0	0
3	1	8	13	3	0	0	0	0	0	0	0
3	1	8	14	4	0	0	0	0	0	0	0
3	1	8	20	8	0	0	0	0	0	0	0
3	1	8	21	6	0	0	0	0	0	0	0
3	1	8	27	1	0	0	0	0	0	0	1
3	1	8	28	2	0	0	0	0	0	0	2
3	2	6	26	184	68	0	0	0	0	0	0
3	2	7	1	127	0	0	46	0	0	48	0
3	2	7	2	167	0	0	52	0	0	71	0
3	2	7	3	183	0	0	61	0	0	84	0
3	2	7	9	40	0	0	0	13	7	0	0
3	2	7	10	229	0	0	0	46	34	0	100
3	2	7	16	203	0	0	0	30	34	0	91
3	2	7	17	271	0	0	0	48	54	0	114
3	2	7	23	112	0	0	0	12	15	0	53
3	2	7	24	107	0	0	0	12	21	0	62
3	2	7	30	52	0	0	0	0	0	0	0
3	2	7	31	5	0	0	0	0	0	0	0
3	2	8	1	83	0	0	0	0	0	0	0
3	2	8	6	108	0	0	0	0	0	0	0
3	2	8	7	122	0	0	0	0	0	0	0
3	2	8	13	25	0	0	0	0	0	0	0
3	2	8	14	28	0	0	0	0	0	0	0
3	2	8	20	31	0	0	0	0	0	0	0
3	2	8	21	29	0	0	0	0	0	0	0
3	2	8	27	13	0	0	0	0	0	0	13
3	2	8	28	33	0	0	17	4	0	0	12
3	3	6	26	41	15	0	0	0	0	0	0
3	3	7	1	13	0	0	6	0	0	6	0
3	3	7	2	21	0	0	6	0	0	8	0
3	3	7	3	20	0	0	5	0	0	11	0
3	3	7	9	12	0	0	0	1	3	0	0
3	3	7	10	39	0	0	0	6	15	0	0
3	3	7	16	9	0	0	0	3	3	0	0
3	3	7	17	21	0	0	0	2	2	0	0
3	3	7	23	22	0	0	0	9	4	0	2
3	3	7	24	59	0	0	0	8	9	0	6
3	3	7	30	5	0	0	0	0	0	0	0
3	3	7	31	1	0	0	0	0	0	0	0
3	3	8	1	34	0	0	0	0	0	0	0
3	3	8	6	11	0	0	0	0	0	0	0
3	3	8	7	8	0	0	0	0	0	0	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
3	3	8	13	4	0	0	0	0	0	0	0
3	3	8	14	7	0	0	0	0	0	0	0
3	3	8	20	5	0	0	0	0	0	0	0
3	3	8	21	4	0	0	0	0	0	0	0
3	3	8	27	1	0	0	0	0	0	0	1
3	3	8	28	2	0	0	2	0	0	0	0
4	1	6	26	6	0	0	0	0	0	0	0
4	1	7	1	9	0	0	0	0	0	0	0
4	1	7	2	7	0	0	0	0	0	0	0
4	1	7	3	15	0	0	0	0	0	0	0
4	1	7	9	13	0	0	0	0	0	0	0
4	1	7	16	10	0	0	0	0	0	0	0
4	1	7	17	8	0	0	0	0	0	0	0
4	1	7	23	19	0	4	0	0	0	3	0
4	1	7	24	25	0	16	0	0	0	4	0
4	1	7	30	7	0	0	5	0	0	2	0
4	2	6	26	118	0	0	0	0	0	54	0
4	2	7	1	78	0	0	0	0	0	0	0
4	2	7	2	117	0	0	0	0	0	0	0
4	2	7	3	91	0	0	0	0	0	0	0
4	2	7	9	47	0	0	0	0	0	0	0
4	2	7	10	104	0	0	0	0	0	0	0
4	2	7	16	94	0	0	0	0	0	0	0
4	2	7	17	98	0	0	0	0	0	0	0
4	2	7	23	53	0	14	3	0	0	6	0
4	2	7	24	168	0	56	0	0	0	49	0
4	2	7	30	7	0	0	2	0	0	5	0
4	3	6	26	10	0	0	0	0	0	3	0
4	3	7	1	23	0	0	0	0	0	0	0
4	3	7	2	20	0	0	0	0	0	0	0
4	3	7	3	10	0	0	0	0	0	0	0
4	3	7	9	17	0	0	0	0	0	0	0
4	3	7	10	51	0	0	0	0	0	0	0
4	3	7	16	6	0	0	0	0	0	0	0
4	3	7	17	22	0	0	0	0	0	0	0
4	3	7	23	55	0	12	8	0	0	7	0
4	3	7	24	109	0	17	0	0	0	12	0
4	3	7	30	41	0	0	21	0	0	8	0
5	1	7	30	13	0	0	1	7	0	0	2
5	1	8	1	39	0	0	11	2	0	2	14
5	2	7	30	158	0	0	4	34	0	4	102
5	2	8	1	197	0	0	46	18	0	19	64
5	3	7	30	9	0	0	3	5	0	0	0
5	3	8	1	51	0	0	8	8	0	3	0
6	1	8	6	23	0	0	0	4	0	0	2
6	1	8	7	35	0	0	0	3	0	0	5

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV1	INTERV2	INTERV3	INTERV4	INTERV5	INTERV6	INTERV7
6	1	8	13	3	0	0	0	0	0	0	0
6	1	8	14	14	0	0	0	4	0	0	10
6	1	8	20	12	0	0	0	2	0	0	7
6	1	8	21	10	0	0	0	1	0	0	7
6	1	8	27	2	0	0	0	1	0	0	1
6	1	8	28	2	0	0	2	0	0	0	0
6	2	8	6	273	0	0	0	87	0	0	116
6	2	8	7	332	0	0	0	63	0	0	133
6	2	8	13	74	0	0	0	0	0	0	0
6	2	8	14	150	0	0	0	51	0	0	99
6	2	8	20	78	0	0	0	23	0	0	31
6	2	8	21	177	0	0	0	22	0	0	96
6	2	8	27	53	0	0	0	8	0	0	45
6	2	8	28	68	0	0	20	25	0	0	23
6	3	8	6	7	0	0	0	1	0	0	2
6	3	8	7	7	0	0	0	1	0	0	1
6	3	8	13	8	0	0	0	0	0	0	0
6	3	8	14	1	0	0	0	0	0	0	1
6	3	8	20	3	0	0	0	1	0	0	1
6	3	8	21	13	0	0	0	1	0	0	6
6	3	8	27	4	0	0	0	4	0	0	0
6	3	8	28	8	0	0	7	1	0	0	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
1	1	6	26	15	0	0	0	0	15	0	0
1	1	7	1	28	7	0	0	0	0	0	0
1	1	7	2	8	0	0	0	0	0	0	0
1	1	7	3	10	0	0	0	0	0	0	0
1	2	6	26	57	0	0	0	0	57	0	0
1	2	7	1	208	54	0	0	0	0	0	0
1	2	7	2	262	0	0	0	0	0	81	0
1	2	7	3	301	0	0	0	0	0	84	0
1	3	6	26	25	0	0	0	0	25	0	0
1	3	7	1	21	16	0	0	0	0	0	0
1	3	7	2	52	0	0	0	0	0	28	0
1	3	7	3	54	0	0	0	0	0	40	0
2	1	6	26	15	0	0	0	0	0	1	0
2	1	7	1	1	0	0	0	0	1	0	0
2	1	7	2	3	0	0	0	0	3	0	0
2	1	7	3	5	0	0	0	0	5	0	0
2	1	7	9	5	0	0	0	0	0	0	1
2	1	7	10	19	7	0	0	0	0	0	7
2	1	7	16	8	2	0	0	0	0	0	2
2	1	7	17	27	6	0	0	0	0	0	11
2	2	6	26	236	0	0	0	0	0	79	0
2	2	7	1	31	0	0	0	0	27	0	0
2	2	7	2	50	0	0	0	0	50	0	0
2	2	7	3	72	0	0	0	0	72	0	0
2	2	7	9	79	21	0	0	0	0	0	15
2	2	7	10	211	68	0	0	0	0	0	38
2	2	7	16	220	60	0	0	0	0	0	26
2	2	7	17	239	82	0	0	0	0	0	54
2	3	6	26	23	0	0	0	0	0	9	0
2	3	7	1	8	0	0	0	0	8	0	0
2	3	7	2	14	0	0	0	0	14	0	0
2	3	7	3	16	0	0	0	0	16	0	0
2	3	7	9	44	11	0	0	0	0	0	8
2	3	7	10	49	12	0	0	0	0	0	18
2	3	7	16	26	4	0	0	0	0	0	5
2	3	7	17	47	9	0	0	0	0	0	5
3	1	6	26	18	0	9	0	9	0	0	0
3	1	7	1	11	0	0	0	0	0	0	4
3	1	7	2	6	0	0	0	0	0	0	2
3	1	7	3	10	0	0	0	0	0	0	2
3	1	7	9	3	0	0	0	0	0	0	0
3	1	7	10	7	0	0	0	0	0	0	0
3	1	7	16	3	0	0	0	0	0	0	0
3	1	7	17	4	0	0	0	0	0	0	0
3	1	7	23	8	0	0	0	0	0	2	0
3	1	7	24	14	2	0	0	0	0	1	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
3	1	7	30	21	0	0	0	0	21	0	0
3	1	8	1	7	0	3	0	0	4	0	0
3	1	8	6	11	0	4	0	0	1	0	6
3	1	8	7	11	6	0	0	0	0	0	5
3	1	8	13	3	0	0	3	0	0	0	0
3	1	8	14	4	0	0	4	0	0	0	0
3	1	8	20	8	0	2	0	0	0	0	6
3	1	8	21	6	0	0	0	0	0	0	6
3	1	8	27	1	0	0	0	0	0	0	0
3	1	8	28	2	0	0	0	0	0	0	0
3	2	6	26	184	0	60	0	56	0	0	0
3	2	7	1	127	0	0	0	0	0	0	33
3	2	7	2	167	0	0	0	0	0	0	44
3	2	7	3	183	0	0	0	0	0	0	38
3	2	7	9	40	0	0	0	0	0	20	0
3	2	7	10	229	0	0	0	0	0	49	0
3	2	7	16	203	0	0	0	0	0	48	0
3	2	7	17	271	0	0	0	0	0	55	0
3	2	7	23	112	0	0	0	0	0	32	0
3	2	7	24	107	6	0	0	0	0	6	0
3	2	7	30	52	0	0	0	0	52	0	0
3	2	7	31	5	0	0	0	0	5	0	0
3	2	8	1	83	0	59	0	0	24	0	0
3	2	8	6	108	0	50	0	0	37	0	21
3	2	8	7	122	53	0	0	0	0	0	69
3	2	8	13	25	0	0	25	0	0	0	0
3	2	8	14	28	0	3	25	0	0	0	0
3	2	8	20	31	0	21	0	0	0	0	10
3	2	8	21	29	0	0	0	0	0	0	29
3	2	8	27	13	0	0	0	0	0	0	0
3	2	8	28	33	0	0	0	0	0	0	0
3	3	6	26	41	0	9	0	17	0	0	0
3	3	7	1	13	0	0	0	0	0	0	1
3	3	7	2	21	0	0	0	0	0	0	7
3	3	7	3	20	0	0	0	0	0	0	4
3	3	7	9	12	0	0	0	0	0	8	0
3	3	7	10	39	0	0	0	0	0	18	0
3	3	7	16	9	0	0	0	0	0	3	0
3	3	7	17	21	0	0	0	0	0	17	0
3	3	7	23	22	0	0	0	0	0	7	0
3	3	7	24	59	10	0	0	0	0	26	0
3	3	7	30	5	0	0	0	0	5	0	0
3	3	7	31	1	0	0	0	0	1	0	0
3	3	8	1	34	0	22	0	0	12	0	0
3	3	8	6	11	0	6	0	0	5	0	0
3	3	8	7	8	6	0	0	0	0	0	2

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
3	3	8	13	4	0	0	4	0	0	0	0
3	3	8	14	7	0	1	6	0	0	0	0
3	3	8	20	5	0	3	0	0	0	0	2
3	3	8	21	4	0	0	0	0	0	0	4
3	3	8	27	1	0	0	0	0	0	0	0
3	3	8	28	2	0	0	0	0	0	0	0
4	1	6	26	6	4	0	0	0	0	0	2
4	1	7	1	9	0	9	0	0	0	0	0
4	1	7	2	7	3	4	0	0	0	0	0
4	1	7	3	15	11	4	0	0	0	0	0
4	1	7	9	13	0	7	0	0	6	0	0
4	1	7	16	10	0	4	0	0	6	0	0
4	1	7	17	8	0	3	0	0	5	0	0
4	1	7	23	19	4	0	0	0	4	0	4
4	1	7	24	25	0	0	0	0	4	0	1
4	1	7	30	7	0	0	0	0	0	0	0
4	2	6	26	118	44	0	0	0	0	0	20
4	2	7	1	78	0	78	0	0	0	0	0
4	2	7	2	117	55	62	0	0	0	0	0
4	2	7	3	91	45	46	0	0	0	0	0
4	2	7	9	47	0	30	0	0	17	0	0
4	2	7	10	104	0	69	0	0	35	0	0
4	2	7	16	94	0	61	0	0	33	0	0
4	2	7	17	98	4	58	0	0	36	0	0
4	2	7	23	53	8	0	0	0	13	0	9
4	2	7	24	168	0	0	0	0	32	0	31
4	2	7	30	7	0	0	0	0	0	0	0
4	3	6	26	10	5	0	0	0	0	0	2
4	3	7	1	23	0	23	0	0	0	0	0
4	3	7	2	20	8	12	0	0	0	0	0
4	3	7	3	10	5	5	0	0	0	0	0
4	3	7	9	17	0	14	0	0	3	0	0
4	3	7	10	51	0	22	0	0	29	0	0
4	3	7	16	6	0	2	0	0	4	0	0
4	3	7	17	22	0	18	0	0	4	0	0
4	3	7	23	55	3	0	0	0	20	0	5
4	3	7	24	109	0	0	0	0	38	0	42
4	3	7	30	41	6	0	0	0	0	0	6
5	1	7	30	13	0	0	0	0	0	0	3
5	1	8	1	39	2	0	0	0	0	8	0
5	2	7	30	158	4	0	0	0	0	0	10
5	2	8	1	197	6	0	0	0	0	44	0
5	3	7	30	9	0	0	0	0	0	0	1
5	3	8	1	51	16	0	0	0	0	16	0
6	1	8	6	23	0	0	0	0	0	17	0
6	1	8	7	35	0	3	0	0	0	24	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	INTERV8	INTERV9	INTERV10	INTERV11	INTERV12	INTERV13	INTERV14
6	1	8	13	3	0	3	0	0	0	0	0
6	1	8	14	14	0	0	0	0	0	0	0
6	1	8	20	12	3	0	0	0	0	0	0
6	1	8	21	10	0	2	0	0	0	0	0
6	1	8	27	2	0	0	0	0	0	0	0
6	1	8	28	2	0	0	0	0	0	0	0
6	2	8	6	273	0	0	0	0	0	70	0
6	2	8	7	332	0	91	0	0	0	45	0
6	2	8	13	74	0	74	0	0	0	0	0
6	2	8	14	150	0	0	0	0	0	0	0
6	2	8	20	78	24	0	0	0	0	0	0
6	2	8	21	177	0	59	0	0	0	0	0
6	2	8	27	53	0	0	0	0	0	0	0
6	2	8	28	68	0	0	0	0	0	0	0
6	3	8	6	7	0	0	0	0	0	4	0
6	3	8	7	7	0	5	0	0	0	0	0
6	3	8	13	8	0	8	0	0	0	0	0
6	3	8	14	1	0	0	0	0	0	0	0
6	3	8	20	3	1	0	0	0	0	0	0
6	3	8	21	13	0	6	0	0	0	0	0
6	3	8	27	4	0	0	0	0	0	0	0
6	3	8	28	8	0	0	0	0	0	0	0

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2	NEWCP1	NEWCP2
1	1	6	26	15	2	13	0	15	0	15	3	12
1	1	7	1	28	5	23	0	28	0	28	9	19
1	1	7	2	8	1	7	0	8	0	8	2	6
1	1	7	3	10	3	7	0	10	0	10	3	7
1	2	6	26	57	9	48	50	7	13	44	9	48
1	2	7	1	208	87	121	185	23	36	172	40	168
1	2	7	2	262	98	164	209	53	52	210	57	205
1	2	7	3	301	114	187	243	58	72	229	68	233
1	3	6	26	25	1	24	0	25	0	25	5	20
1	3	7	1	21	1	20	0	21	0	21	7	14
1	3	7	2	52	1	51	0	52	0	52	15	37
1	3	7	3	54	15	39	0	54	0	54	7	47
2	1	6	26	15	2	13	0	15	0	15	9	6
2	1	7	1	1	1	0	0	1	0	1	0	1
2	1	7	2	3	0	3	0	3	0	3	0	3
2	1	7	3	5	0	5	0	5	0	5	1	4
2	1	7	9	5	2	3	0	5	0	5	1	4
2	1	7	10	19	6	13	0	19	0	19	8	11
2	1	7	16	8	4	4	0	8	0	8	4	4
2	1	7	17	27	5	22	0	27	0	27	5	22
2	2	6	26	236	46	190	186	50	88	148	42	194
2	2	7	1	31	12	19	30	1	1	30	5	26
2	2	7	2	50	18	32	45	5	2	48	7	43
2	2	7	3	72	8	64	55	17	6	66	14	58
2	2	7	9	79	38	41	69	10	16	63	17	62
2	2	7	10	211	62	149	157	54	35	176	42	169
2	2	7	16	220	132	88	166	54	60	160	56	164
2	2	7	17	239	107	132	170	69	41	198	51	188
2	3	6	26	23	0	23	0	23	0	23	11	12
2	3	7	1	8	0	8	0	8	0	8	2	6
2	3	7	2	14	0	14	0	14	0	14	5	9
2	3	7	3	16	0	16	0	16	0	16	2	14
2	3	7	9	44	14	30	0	44	0	44	14	30
2	3	7	10	49	6	43	0	49	0	49	16	33
2	3	7	16	26	2	24	0	26	0	26	8	18
2	3	7	17	47	18	29	0	47	0	47	9	38
3	1	6	26	18	1	17	0	18	0	18	7	11
3	1	7	1	11	5	6	0	11	0	11	5	6
3	1	7	2	6	4	2	0	6	0	6	2	4
3	1	7	3	10	2	8	0	10	0	10	3	7
3	1	7	9	3	0	3	0	3	0	3	2	1
3	1	7	10	7	1	6	0	7	0	7	5	2
3	1	7	16	3	0	3	0	3	0	3	3	0
3	1	7	17	4	1	3	0	4	0	4	2	2
3	1	7	23	8	2	6	0	8	0	8	2	6
3	1	7	24	14	2	12	0	14	0	14	6	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2	NEWCP1	NEWCP2
3	1	7	30	21	1	20	0	21	0	21	3	18
3	1	8	1	7	4	3	0	7	0	7	2	5
3	1	8	6	11	1	10	0	11	0	11	5	6
3	1	8	7	11	3	8	0	11	0	11	3	8
3	1	8	13	3	0	3	0	3	0	3	1	2
3	1	8	14	4	0	4	0	4	0	4	2	2
3	1	8	20	8	1	7	0	8	0	8	4	4
3	1	8	21	6	3	3	0	6	0	6	2	4
3	1	8	27	1	1	0	0	1	0	1	0	1
3	1	8	28	2	0	2	0	2	0	2	1	1
3	2	6	26	184	70	114	155	29	57	127	48	136
3	2	7	1	127	74	53	92	35	21	106	33	94
3	2	7	2	167	93	74	130	37	39	128	41	126
3	2	7	3	183	62	121	129	54	26	157	45	138
3	2	7	9	40	22	18	28	12	11	29	8	32
3	2	7	10	229	68	161	181	48	57	172	44	185
3	2	7	16	203	134	69	179	24	64	139	41	162
3	2	7	17	271	118	153	235	36	73	198	62	209
3	2	7	23	112	28	84	92	20	15	97	20	92
3	2	7	24	107	30	77	88	19	27	80	17	90
3	2	7	30	52	15	37	47	5	13	39	10	42
3	2	7	31	5	3	2	5	0	5	0	1	4
3	2	8	1	83	38	45	65	18	34	49	17	66
3	2	8	6	108	52	56	103	5	14	94	22	86
3	2	8	7	122	52	70	87	35	7	115	29	93
3	2	8	13	25	17	8	19	6	2	23	6	19
3	2	8	14	28	10	18	16	12	1	27	9	19
3	2	8	20	31	16	15	25	6	13	18	5	26
3	2	8	21	29	3	26	25	4	1	28	7	22
3	2	8	27	13	3	10	13	0	8	5	4	9
3	2	8	28	33	19	14	31	2	11	22	6	27
3	3	6	26	41	5	36	0	41	0	41	13	28
3	3	7	1	13	3	10	0	13	0	13	6	7
3	3	7	2	21	2	19	0	21	0	21	9	12
3	3	7	3	20	1	19	0	20	0	20	5	15
3	3	7	9	12	1	11	0	12	0	12	4	8
3	3	7	10	39	2	37	0	39	0	39	15	24
3	3	7	16	9	5	4	0	9	0	9	3	6
3	3	7	17	21	4	17	0	21	0	21	4	17
3	3	7	23	22	7	15	0	22	0	22	9	13
3	3	7	24	59	0	59	0	59	0	59	19	40
3	3	7	30	5	0	5	0	5	0	5	1	4
3	3	7	31	1	1	0	0	1	0	1	0	1
3	3	8	1	34	8	26	0	34	0	34	7	27
3	3	8	6	11	1	10	0	11	0	11	4	7
3	3	8	7	8	0	8	0	8	0	8	2	6

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2	NEWCP1	NEWCP2
3	3	8	13	4	0	4	0	4	0	4	1	3
3	3	8	14	7	0	7	0	7	0	7	2	5
3	3	8	20	5	0	5	0	5	0	5	1	4
3	3	8	21	4	0	4	0	4	0	4	2	2
3	3	8	27	1	0	1	0	1	0	1	0	1
3	3	8	28	2	0	2	0	2	0	2	1	1
4	1	6	26	6	2	4	0	6	0	6	3	3
4	1	7	1	9	4	5	0	9	0	9	6	3
4	1	7	2	7	0	7	0	7	0	7	4	3
4	1	7	3	15	2	13	0	15	0	15	5	10
4	1	7	9	13	0	13	0	13	0	13	3	10
4	1	7	16	10	4	6	0	10	0	10	4	6
4	1	7	17	8	2	6	0	8	0	8	2	6
4	1	7	23	19	3	16	0	19	0	19	6	13
4	1	7	24	25	5	20	0	25	0	25	3	22
4	1	7	30	7	2	5	0	7	0	7	2	5
4	2	6	26	118	58	60	90	28	23	95	38	80
4	2	7	1	78	36	42	56	22	26	52	15	63
4	2	7	2	117	60	57	97	20	46	71	32	85
4	2	7	3	91	57	34	82	9	22	69	30	61
4	2	7	9	47	23	24	36	11	2	45	14	33
4	2	7	10	104	18	86	76	28	19	85	26	78
4	2	7	16	94	34	60	78	16	12	82	20	74
4	2	7	17	98	20	78	81	17	25	73	20	78
4	2	7	23	53	20	33	44	9	8	45	12	41
4	2	7	24	168	50	118	145	23	27	141	23	145
4	2	7	30	7	4	3	5	2	3	4	1	6
4	3	6	26	10	3	7	0	10	0	10	3	7
4	3	7	1	23	2	21	0	23	0	23	10	13
4	3	7	2	20	6	14	0	20	0	20	6	14
4	3	7	3	10	2	8	0	10	0	10	0	10
4	3	7	9	17	2	15	0	17	0	17	5	12
4	3	7	10	51	1	50	0	51	0	51	10	41
4	3	7	16	6	2	4	0	6	0	6	1	5
4	3	7	17	22	6	16	0	22	0	22	6	16
4	3	7	23	55	8	47	0	55	0	55	14	41
4	3	7	24	109	14	95	0	109	0	109	35	74
4	3	7	30	41	8	33	0	41	0	41	9	32
5	1	7	30	13	5	8	0	13	0	13	8	5
5	1	8	1	39	13	26	0	39	0	39	10	29
5	2	7	30	158	55	103	141	17	49	109	31	127
5	2	8	1	197	80	117	174	23	48	149	41	156
5	3	7	30	9	1	8	0	9	0	9	2	7
5	3	8	1	51	11	40	0	51	0	51	13	38
6	1	8	6	23	5	18	0	23	0	23	9	14
6	1	8	7	35	13	22	0	35	0	35	14	21

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSBA1	NEWSBA2	HEADUND1	HEADUND2	SWALLOW1	SWALLOW2	NEWCP1	NEWCP2
6	1	8	13	3	0	3	0	3	0	3	1	2
6	1	8	14	14	2	12	0	14	0	14	8	6
6	1	8	20	12	2	10	0	12	0	12	5	7
6	1	8	21	10	3	7	0	10	0	10	5	5
6	1	8	27	2	1	1	0	2	0	2	1	1
6	1	8	28	2	2	0	0	2	0	2	1	1
6	2	8	6	273	116	157	253	20	111	162	65	208
6	2	8	7	332	146	186	298	34	105	227	76	256
6	2	8	13	74	52	22	70	4	50	24	15	59
6	2	8	14	150	64	86	145	5	52	98	31	119
6	2	8	20	78	31	47	75	3	35	43	17	61
6	2	8	21	177	80	97	163	14	66	111	40	137
6	2	8	27	53	34	19	50	3	21	32	10	43
6	2	8	28	68	29	39	59	9	21	47	15	53
6	3	8	6	7	0	7	0	7	0	7	3	4
6	3	8	7	7	0	7	0	7	0	7	1	6
6	3	8	13	8	3	5	0	8	0	8	3	5
6	3	8	14	1	1	0	0	1	0	1	0	1
6	3	8	20	3	1	2	0	3	0	3	1	2
6	3	8	21	13	6	7	0	13	0	13	3	10
6	3	8	27	4	0	4	0	4	0	4	2	2
6	3	8	28	8	0	8	0	8	0	8	3	5

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
1	1	6	26	15	1	14	1	14	1	14
1	1	7	1	28	1	27	0	28	0	28
1	1	7	2	8	0	8	0	8	0	8
1	1	7	3	10	0	10	0	10	0	10
1	2	6	26	57	3	54	0	57	2	55
1	2	7	1	208	10	198	3	205	5	203
1	2	7	2	262	15	247	0	262	6	256
1	2	7	3	301	19	282	4	297	10	291
1	3	6	26	25	0	25	0	25	0	25
1	3	7	1	21	0	21	0	21	0	21
1	3	7	2	52	1	51	1	51	0	52
1	3	7	3	54	0	54	0	54	0	54
2	1	6	26	15	0	15	0	15	0	15
2	1	7	1	1	0	1	0	1	0	1
2	1	7	2	3	0	3	0	3	0	3
2	1	7	3	5	0	5	0	5	0	5
2	1	7	9	5	0	5	0	5	0	5
2	1	7	10	19	2	17	0	19	2	17
2	1	7	16	8	1	7	0	8	1	7
2	1	7	17	27	1	26	0	27	1	26
2	2	6	26	236	15	221	5	231	4	232
2	2	7	1	31	0	31	0	31	0	31
2	2	7	2	50	2	48	1	49	1	49
2	2	7	3	72	5	67	4	68	2	70
2	2	7	9	79	6	73	2	77	1	78
2	2	7	10	211	17	194	2	209	5	206
2	2	7	16	220	34	186	13	207	17	203
2	2	7	17	239	30	209	6	233	9	230
2	3	6	26	23	0	23	0	23	0	23
2	3	7	1	8	0	8	0	8	0	8
2	3	7	2	14	0	14	0	14	0	14
2	3	7	3	16	0	16	0	16	0	16
2	3	7	9	44	1	43	0	44	1	43
2	3	7	10	49	0	49	0	49	0	49
2	3	7	16	26	0	26	0	26	0	26
2	3	7	17	47	0	47	0	47	0	47
3	1	6	26	18	2	16	1	17	0	18
3	1	7	1	11	1	10	0	11	0	11
3	1	7	2	6	1	5	0	6	1	5
3	1	7	3	10	0	10	0	10	0	10
3	1	7	9	3	0	3	0	3	0	3
3	1	7	10	7	0	7	0	7	0	7
3	1	7	16	3	0	3	0	3	0	3
3	1	7	17	4	0	4	0	4	0	4
3	1	7	23	8	0	8	0	8	0	8
3	1	7	24	14	2	12	1	13	1	13

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
3	1	7	30	21	1	20	1	20	0	21
3	1	8	1	7	0	7	0	7	0	7
3	1	8	6	11	0	11	0	11	0	11
3	1	8	7	11	1	10	0	11	1	10
3	1	8	13	3	0	3	0	3	0	3
3	1	8	14	4	0	4	0	4	0	4
3	1	8	20	8	0	8	0	8	0	8
3	1	8	21	6	0	6	0	6	0	6
3	1	8	27	1	0	1	0	1	0	1
3	1	8	28	2	0	2	0	2	0	2
3	2	6	26	184	12	172	2	182	5	179
3	2	7	1	127	15	112	6	121	5	122
3	2	7	2	167	24	143	9	158	15	152
3	2	7	3	183	20	163	6	177	6	177
3	2	7	9	40	3	37	1	39	0	40
3	2	7	10	229	11	218	1	228	6	223
3	2	7	16	203	13	190	5	198	3	200
3	2	7	17	271	19	252	3	268	7	264
3	2	7	23	112	6	106	0	112	3	109
3	2	7	24	107	3	104	0	107	2	105
3	2	7	30	52	3	49	1	51	2	50
3	2	7	31	5	0	5	0	5	0	5
3	2	8	1	83	4	79	0	83	2	81
3	2	8	6	108	4	104	2	106	1	107
3	2	8	7	122	7	115	1	121	3	119
3	2	8	13	25	1	24	0	25	0	25
3	2	8	14	28	0	28	0	28	0	28
3	2	8	20	31	1	30	1	30	0	31
3	2	8	21	29	5	24	1	28	3	26
3	2	8	27	13	3	10	1	12	1	12
3	2	8	28	33	4	29	0	33	2	31
3	3	6	26	41	3	38	1	40	1	40
3	3	7	1	13	1	12	1	12	0	13
3	3	7	2	21	1	20	0	21	1	20
3	3	7	3	20	1	19	0	20	1	19
3	3	7	9	12	0	12	0	12	0	12
3	3	7	10	39	0	39	0	39	0	39
3	3	7	16	9	0	9	0	9	0	9
3	3	7	17	21	1	20	0	21	0	21
3	3	7	23	22	0	22	0	22	0	22
3	3	7	24	59	1	58	0	59	0	59
3	3	7	30	5	0	5	0	5	0	5
3	3	7	31	1	0	1	0	1	0	1
3	3	8	1	34	0	34	0	34	0	34
3	3	8	6	11	0	11	0	11	0	11
3	3	8	7	8	0	8	0	8	0	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
3	3	8	13	4	0	4	0	4	0	4
3	3	8	14	7	0	7	0	7	0	7
3	3	8	20	5	0	5	0	5	0	5
3	3	8	21	4	0	4	0	4	0	4
3	3	8	27	1	0	1	0	1	0	1
3	3	8	28	2	0	2	0	2	0	2
4	1	6	26	6	0	6	0	6	0	6
4	1	7	1	9	1	8	0	9	1	8
4	1	7	2	7	0	7	0	7	0	7
4	1	7	3	15	2	13	2	13	0	15
4	1	7	9	13	1	12	0	13	0	13
4	1	7	16	10	0	10	0	10	0	10
4	1	7	17	8	0	8	0	8	0	8
4	1	7	23	19	1	18	0	19	0	19
4	1	7	24	25	3	22	1	24	0	25
4	1	7	30	7	0	7	0	7	0	7
4	2	6	26	118	18	100	6	112	3	115
4	2	7	1	78	19	59	1	77	12	66
4	2	7	2	117	30	87	2	115	19	98
4	2	7	3	91	19	72	9	82	8	83
4	2	7	9	47	2	45	1	46	2	45
4	2	7	10	104	4	100	0	104	2	102
4	2	7	16	94	6	88	4	90	2	92
4	2	7	17	98	8	90	4	94	5	93
4	2	7	23	53	4	49	3	50	0	53
4	2	7	24	168	12	156	5	163	5	163
4	2	7	30	7	1	6	0	7	0	7
4	3	6	26	10	0	10	0	10	0	10
4	3	7	1	23	2	21	0	23	1	22
4	3	7	2	20	3	17	0	20	1	19
4	3	7	3	10	0	10	0	10	0	10
4	3	7	9	17	3	14	0	17	0	17
4	3	7	10	51	2	49	2	49	0	51
4	3	7	16	6	0	6	0	6	0	6
4	3	7	17	22	0	22	0	22	0	22
4	3	7	23	55	1	54	0	55	0	55
4	3	7	24	109	0	109	0	109	0	109
4	3	7	30	41	1	40	0	41	1	40
5	1	7	30	13	0	13	0	13	0	13
5	1	8	1	39	0	39	0	39	0	39
5	2	7	30	158	6	152	0	158	5	153
5	2	8	1	197	12	185	8	189	2	195
5	3	7	30	9	0	9	0	9	0	9
5	3	8	1	51	1	50	1	50	0	51
6	1	8	6	23	2	21	2	21	0	23
6	1	8	7	35	0	35	0	35	0	35

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWILL1	NEWILL2	NEWGI1	NEWGI2	NEWRES1	NEWRES2
6	1	8	13	3	0	3	0	3	0	3
6	1	8	14	14	0	14	0	14	0	14
6	1	8	20	12	0	12	0	12	0	12
6	1	8	21	10	0	10	0	10	0	10
6	1	8	27	2	0	2	0	2	0	2
6	1	8	28	2	0	2	0	2	0	2
6	2	8	6	273	7	266	5	268	2	271
6	2	8	7	332	20	312	11	321	8	324
6	2	8	13	74	3	71	0	74	2	72
6	2	8	14	150	5	145	0	150	2	148
6	2	8	20	78	7	71	0	78	3	75
6	2	8	21	177	6	171	3	174	2	175
6	2	8	27	53	5	48	2	51	3	50
6	2	8	28	68	3	65	0	68	1	67
6	3	8	6	7	0	7	0	7	0	7
6	3	8	7	7	0	7	0	7	0	7
6	3	8	13	8	0	8	0	8	0	8
6	3	8	14	1	0	1	0	1	0	1
6	3	8	20	3	0	3	0	3	0	3
6	3	8	21	13	0	13	0	13	0	13
6	3	8	27	4	0	4	0	4	0	4
6	3	8	28	8	0	8	0	8	0	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
3	1	7	30	21	0	21	0	21	0	21
3	1	8	1	7	0	7	0	7	0	7
3	1	8	6	11	0	11	0	11	0	11
3	1	8	7	11	0	11	0	11	0	11
3	1	8	13	3	0	3	0	3	0	3
3	1	8	14	4	0	4	0	4	0	4
3	1	8	20	8	0	8	0	8	0	8
3	1	8	21	6	0	6	0	6	0	6
3	1	8	27	1	0	1	0	1	0	1
3	1	8	28	2	0	2	0	2	0	2
3	2	6	26	184	4	180	2	182	1	183
3	2	7	1	127	1	126	1	126	2	125
3	2	7	2	167	2	165	3	164	4	163
3	2	7	3	183	2	181	1	182	3	180
3	2	7	9	40	0	40	2	38	0	40
3	2	7	10	229	2	227	0	229	0	229
3	2	7	16	203	1	202	1	202	3	200
3	2	7	17	271	1	270	8	263	0	271
3	2	7	23	112	0	112	0	112	2	110
3	2	7	24	107	0	107	0	107	1	106
3	2	7	30	52	0	52	1	51	0	52
3	2	7	31	5	0	5	0	5	0	5
3	2	8	1	83	0	83	0	83	2	81
3	2	8	6	108	0	108	0	108	0	108
3	2	8	7	122	1	121	3	119	1	121
3	2	8	13	25	0	25	0	25	1	24
3	2	8	14	28	0	28	0	28	0	28
3	2	8	20	31	0	31	0	31	0	31
3	2	8	21	29	1	28	1	28	0	29
3	2	8	27	13	1	12	0	13	0	13
3	2	8	28	33	0	33	0	33	0	33
3	3	6	26	41	0	41	0	41	0	41
3	3	7	1	13	0	13	0	13	0	13
3	3	7	2	21	0	21	1	20	0	21
3	3	7	3	20	0	20	0	20	0	20
3	3	7	9	12	0	12	0	12	0	12
3	3	7	10	39	0	39	0	39	0	39
3	3	7	16	9	0	9	0	9	0	9
3	3	7	17	21	0	21	0	21	0	21
3	3	7	23	22	0	22	0	22	0	22
3	3	7	24	59	0	59	0	59	0	59
3	3	7	30	5	0	5	0	5	0	5
3	3	7	31	1	0	1	0	1	0	1
3	3	8	1	34	0	34	0	34	0	34
3	3	8	6	11	0	11	0	11	0	11
3	3	8	7	8	0	8	0	8	0	8

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
3	3	8	13	4	0	4	0	4	0	4
3	3	8	14	7	0	7	0	7	0	7
3	3	8	20	5	0	5	0	5	0	5
3	3	8	21	4	0	4	0	4	0	4
3	3	8	27	1	0	1	0	1	0	1
3	3	8	28	2	0	2	0	2	0	2
4	1	6	26	6	0	6	0	6	0	6
4	1	7	1	9	0	9	0	9	1	8
4	1	7	2	7	0	7	0	7	0	7
4	1	7	3	15	0	15	0	15	0	15
4	1	7	9	13	0	13	0	13	0	13
4	1	7	16	10	0	10	0	10	0	10
4	1	7	17	8	0	8	0	8	0	8
4	1	7	23	19	0	19	0	19	0	19
4	1	7	24	25	0	25	0	25	0	25
4	1	7	30	7	0	7	0	7	0	7
4	2	6	26	118	5	113	1	117	2	116
4	2	7	1	78	0	78	1	77	4	74
4	2	7	2	117	4	113	4	113	4	113
4	2	7	3	91	2	89	3	88	2	89
4	2	7	9	47	0	47	0	47	0	47
4	2	7	10	104	0	104	1	103	1	103
4	2	7	16	94	0	94	1	93	0	94
4	2	7	17	98	1	97	0	98	4	94
4	2	7	23	53	1	52	0	53	0	53
4	2	7	24	168	1	167	1	167	3	165
4	2	7	30	7	1	6	0	7	0	7
4	3	6	26	10	0	10	0	10	0	10
4	3	7	1	23	0	23	0	23	0	23
4	3	7	2	20	0	20	2	18	1	19
4	3	7	3	10	0	10	0	10	0	10
4	3	7	9	17	3	14	0	17	0	17
4	3	7	10	51	0	51	0	51	0	51
4	3	7	16	6	0	6	0	6	0	6
4	3	7	17	22	0	22	0	22	0	22
4	3	7	23	55	0	55	0	55	0	55
4	3	7	24	109	0	109	0	109	0	109
4	3	7	30	41	0	41	0	41	0	41
5	1	7	30	13	0	13	0	13	0	13
5	1	8	1	39	0	39	0	39	0	39
5	2	7	30	158	0	158	0	158	2	156
5	2	8	1	197	0	197	1	196	1	196
5	3	7	30	9	0	9	0	9	0	9
5	3	8	1	51	0	51	0	51	0	51
6	1	8	6	23	0	23	0	23	0	23
6	1	8	7	35	0	35	0	35	0	35

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
1	1	6	26	15	0	15	0	15	0	15
1	1	7	1	28	0	28	0	28	0	28
1	1	7	2	8	0	8	0	8	0	8
1	1	7	3	10	0	10	0	10	0	10
1	2	6	26	57	0	57	1	56	0	57
1	2	7	1	208	1	207	0	208	2	206
1	2	7	2	262	1	261	0	262	1	261
1	2	7	3	301	1	300	0	301	1	300
1	3	6	26	25	0	25	0	25	0	25
1	3	7	1	21	0	21	0	21	0	21
1	3	7	2	52	0	52	0	52	0	52
1	3	7	3	54	0	54	0	54	0	54
2	1	6	26	15	0	15	0	15	0	15
2	1	7	1	1	0	1	0	1	0	1
2	1	7	2	3	0	3	0	3	0	3
2	1	7	3	5	0	5	0	5	0	5
2	1	7	9	5	0	5	0	5	0	5
2	1	7	10	19	0	19	1	18	1	18
2	1	7	16	8	0	8	1	7	0	8
2	1	7	17	27	1	26	0	27	0	27
2	2	6	26	236	0	236	2	234	3	233
2	2	7	1	31	0	31	0	31	0	31
2	2	7	2	50	0	50	0	50	0	50
2	2	7	3	72	2	70	0	72	0	72
2	2	7	9	79	0	79	2	77	3	76
2	2	7	10	211	4	207	2	209	0	211
2	2	7	16	220	7	213	2	218	3	217
2	2	7	17	239	7	232	8	231	5	234
2	3	6	26	23	0	23	0	23	0	23
2	3	7	1	8	0	8	0	8	0	8
2	3	7	2	14	0	14	0	14	0	14
2	3	7	3	16	0	16	0	16	0	16
2	3	7	9	44	0	44	0	44	1	43
2	3	7	10	49	0	49	0	49	0	49
2	3	7	16	26	0	26	0	26	0	26
2	3	7	17	47	0	47	0	47	0	47
3	1	6	26	18	0	18	1	17	0	18
3	1	7	1	11	0	11	0	11	1	10
3	1	7	2	6	0	6	0	6	0	6
3	1	7	3	10	0	10	0	10	0	10
3	1	7	9	3	0	3	0	3	0	3
3	1	7	10	7	0	7	0	7	0	7
3	1	7	16	3	0	3	0	3	0	3
3	1	7	17	4	0	4	0	4	0	4
3	1	7	23	8	0	8	0	8	0	8
3	1	7	24	14	0	14	0	14	0	14

Table 9.8 Continued

BEACH	WADESWIM	MONTH	DATE	N	NEWSKIN1	NEWSKIN2	NEWEYE1	NEWEYE2	NEWEAR1	NEWEAR2
6	1	8	13	3	0	3	0	3	0	3
6	1	8	14	14	0	14	0	14	0	14
6	1	8	20	12	0	12	0	12	0	12
6	1	8	21	10	0	10	0	10	0	10
6	1	8	27	2	0	2	0	2	0	2
6	1	8	28	2	0	2	0	2	0	2
6	2	8	6	273	0	273	1	272	0	273
6	2	8	7	332	0	332	2	330	2	330
6	2	8	13	74	1	73	0	74	0	74
6	2	8	14	150	0	150	2	148	0	150
6	2	8	20	78	1	77	2	76	0	78
6	2	8	21	177	0	177	0	177	1	176
6	2	8	27	53	0	53	0	53	0	53
6	2	8	28	68	0	68	1	67	0	68
6	3	8	6	7	0	7	0	7	0	7
6	3	8	7	7	0	7	0	7	0	7
6	3	8	13	8	0	8	0	8	0	8
6	3	8	14	1	0	1	0	1	0	1
6	3	8	20	3	0	3	0	3	0	3
6	3	8	21	13	0	13	0	13	0	13
6	3	8	27	4	0	4	0	4	0	4
6	3	8	28	8	0	8	0	8	0	8

Table 9.8 Continued

Legend:

Beach: see Table 9.1

Ag: number of persons

Sex: 1 - male, 2- female

Food: 1 - no food and/or drink consumed at beach
2 - food and/or drink brought from home and consumed at beach
3 - food and/or drink bought at beach and consumed at beach
4 - food and/or drink brought from home and bought at beach consumed on beach

Newse1 - high SES (SocioEconomic Status)
Newse2 - middle SES
Newse3 - low SES (see Table 5.8)

Newcp1 - number of contact persons
Newcp2 - number of non-contact persons

Ital1 - number of italians
Ital2 - number of non-Italians

Wadeswm1 - number of waders
Wadeswm2 - number of swimmers
Wadeswm3 - number of persons who did not enter the water

Interv1-14 - interviewers

Newsba1 - number of persons who swam or went in the water 4 days before, or 3 days after the interview day
Newsba2 - number of persons who did not swim or go into the water 4 days before, or 3 days after the interview day

Headund1 - number of persons who put their head under the water
Headund2 - number of persons who did not put their heads under the water

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Table 9.8 Continued

Legend:

Swallow1 - number of persons who swallowed water
Swallow2 - number of persons who did not swallow water
Newill1 - number of ill persons
Newill2 - number of persons not ill

Newgi1 - number of persons with GI symptoms
Newgi2 - number of persons without GI symptoms

Newres1 - number of persons with respiratory symptoms
Newres2 - number of persons with no respiratory symptoms

Newskin1 - number of persons with skin problems
Newskin2 - number of persons with no skin problems

Neweye1 - number of persons with eye problems
Neweye2 - Number of persons without eye problems

Newear1 - number of persons with ear problems
Newear2 - number of persons without ear problems

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